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Notes on the Stages and the Biology of *Baryodma ontarionis* Casey (Coleoptera: Staphylinidae), a Parasite of the Cabbage Maggot, *Hylemya brassicae* Bouché (Diptera: Anthomyiidae)[1]

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Introduction

During investigations on the natural enemies of root maggots attacking Cruciferae, the beetle *Baryodma ontarionis* Casey was reared from puparia of the cabbage maggot, *Hylemya brassicae* (Bouché). This was not unexpected, for Gibson and Treherne (1916) had reported a similar occurrence; the staphylinid beetles reared at that time were identified by Casey (1916), who decided that they belonged to the *verna* group of *Baryodma* and assigned the name *Baryodma ontarionis*. Casey (loc. cit.) considered the species rather common and stated that it did not seem to resemble any European species; but Mr. W. J. Brown (in litt.), Systematic Entomology, Division of Entomology, Ottawa, who identified the beetles collected in 1950, is of the opinion that *B. ontarionis* is synonymous with *Aleochara bilineata* Gyll., which attacks the cabbage maggot in Europe. Wadsworth (1915) dealt with the biology of *A. bilineata*, giving detailed descriptions of the immature stages. A study of the biology of *B. ontarionis* was carried out at the Belleville laboratory as part of a program of parasite introduction with the purpose in view of using the information to evaluate the beetle as a factor in the control of root maggots that are severe pests of cabbage, cauliflower, turnip, and radish.

Methods

Puparia of *Hylemya brassicae* were collected from soil around infested turnips and were placed singly in two-inch shell vials. These were stoppered by inserting a quarter-inch length of rubber tubing sheathed with a half-inch square of fine-mesh rayon cloth. This type of stopper served the dual purpose of preventing the escape of beetles and providing a means of ventilating the vials. The vials were laid horizontally in rows on enamelled "butcher" trays, which were then placed in tiers in a humidity cabinet. Rearing was carried out at a temperature of 23.8°C. and a relative humidity of 75 per cent; humidity was maintained by placing pans of water on the floor of the cabinet. *H. brassicae* puparia parasitized in the laboratory were treated in the same manner.

Adults of *B. ontarionis* were given larvae of *Musca domestica* L. and of *Drosophila melanogaster* Meig. as food. Treherne (1915) fed the staphylinid beetle *Gyrohypnus hamatus* (Say) larvae of the cabbage maggot, but these were not obtainable in sufficient quantities for the adults of *B. ontarionis*. The beetles were placed in stender dishes two and one-half inches in diameter, the bottoms being covered with moistened green blotting paper; at 24-hour intervals each beetle was given more than sufficient larvae.

Puparia of the cabbage maggot were put into the dishes to stimulate oviposition. At 24-hour intervals the blotting paper was changed and the eggs were counted. The eggs were removed with a fine probe and transferred to other stender dishes. Blotting paper saturated with water was used to cover

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the bottoms of these dishes. The stender dishes were left in the humidity cabinet when not under observation.

Description of the Stages

Adult.—The adult was described by Casey (1916). It is glossy black and pubescent, the hairs being short and coarse. Females are usually larger than males, but there are no apparent secondary sexual characters. The average size of the female is 5.81 mm. and that of the male is 5.40 mm.

Egg.—The colour of the egg varies depending upon the colour of the gelantinous substance surrounding the chorion. When this substance is removed the egg is pearly white. It is ellipsoid in shape and is 0.50 x 0.37 mm.

First-stage larva.—The first-stage larva, campodeiform in type, is pale brownish with white intersegmental areas and varies from 1.25 x 0.25 mm. in size just after eclosion to 2.25 x 0.37 mm. when full-grown. The head capsule, mandibles, legs, and anal region are darker brown in colour than the rest of the body. The abdomen is covered with long setae. The tarsal claws are well developed. Cerci are present. The tip of the abdomen is produced into a cup-like projection.

Second-stage larva.—The early second-stage larva, eruciform in type, is glistening white and the cuticle is lightly sclerotized. Just after moulting it measures 2.75 mm. in length and when fully grown measures 3.69 mm. The anal cerci have disappeared, the tarsal claws are not evident, and the legs are rudimentary. The full-grown second-stage larva is also glistening white in colour.

Third-stage larva.—The third-stage larva is similar to the second. The cuticle is more heavily sclerotized, the head capsule is darker, the mandibles are more prominent, and the body is creamy white. The maximum size is 5.33 x 1.64 mm.

Pupa.—The pupa is 4.66 mm. in length. It is creamy white at first, but becomes brown, then black, as pigmentation progresses. The tip of the abdomen shows the first signs of pigmentation.

Biology

When beetles were placed in oviposition dishes copulation occurred immediately. There was no apparent courtship period or mating play. When in close proximity to a female, the male flexed the abdomen over its head, extruded the claspers, and was at once in position for copulation (Fig. 1). During copulation females often moved about the container with the males still attached. Mating occurred frequently during the oviposition period but it was not determined whether this was conducive to the high fertility of the eggs deposited in the laboratory. The observed maximum period for copulation was 65 seconds and the minimum 20 seconds.

The pre-oviposition period varied from 36 to 96 hours and the mean for a sample of 20 females was 48 hours. The pre-oviposition period for *A. bilineata* was determined by Wadsworth (1915) as 48 hours.

Females oviposited readily in the oviposition dishes but showed no preference for laying eggs on or near puparia of *H. brassicae*. Eggs were laid indiscriminately on the blotting paper, on the sides of the stender dishes, and on the puparia (Fig. 2). Eggs were also laid in dishes containing no puparia but this may have been due to the inability of the females to retain developed ova. Copper-coated pellets were put into the stender dishes containing puparia, and 95 per cent of the eggs were laid on or between the pellets. In some stender dishes eggs were not laid on or near the puparia. It is possible that the pellets

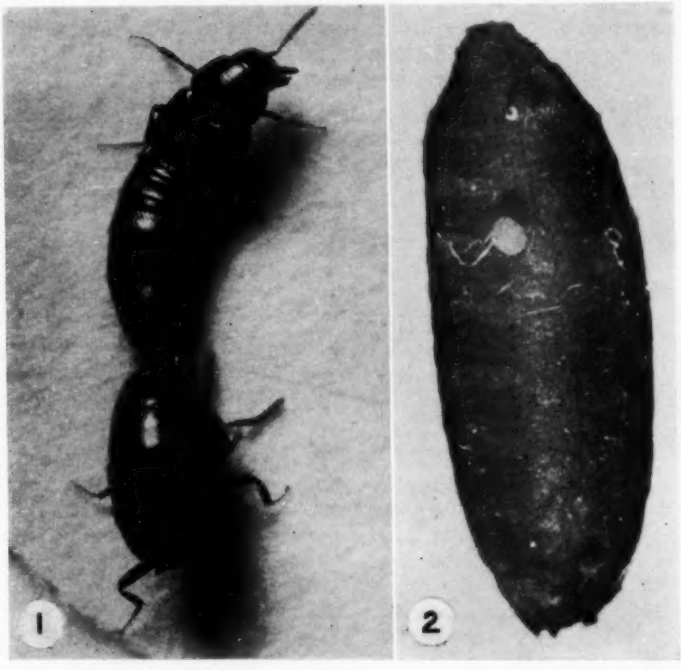

Fig. 1. Copulation of *Baryodma ontarionis*.

Fig. 2. An egg laid upon a puparium of *Hylemya brassicae*.

resembled large soil particles to the females and that in the field the females of *B. ontarionis* deposit eggs in the soil near the roots of cabbage infested with the cabbage maggot, as Wadsworth (1915) reported for *A. bilineata*.

Starved females copulated frequently but did not oviposit. Dissection showed the ovaries to be undeveloped.

Fed females continued ovipositing during their lives. Table I shows the numbers of eggs laid by 12 fed females and the lengths of their lives. The number of eggs per female varied considerably, from 543 to 989; the average was 710. One female laid a total of 40 eggs in a single day but the daily average was 14.9.

TABLE I

Lengths of life of and numbers of eggs laid by 12 females of *Baryodma ontarionis* reared at 23.8°C. and 75 per cent relative humidity.

Length of life in days	Number of eggs laid
38	543
39	573
41	345
41	590
42	816
48	762
49	830
53	927
54	612
55	588
55	989
57	946

The eggs of *B. ontarionis* hatched in three to seven days. Seventy-six per cent of 2,880 eggs, laid on 20 consecutive days, hatched on the fifth day. Wadsworth (1915) showed that the eggs of *A. bilineata* hatch in 12 to 14 days, but this work was carried out in moist soil cultures and the exact rearing temperature was not stated.

Twenty-four hours before eclosion the mandibles, eye spots, antennae, and legs of the larva are visible through the chorion. The larva is then in a curled position along the longitudinal axis of the egg. The mandibles move constantly and at the moment of hatching rupture the chorion, the pressure of the head assisting in this process. The head and the thorax appear, and by twisting movements the larva soon frees itself from the chorion. Eclosion takes place in five to ten seconds.

The larva were very active and moved over the blotting paper in the stender dishes until a puparium was encountered. The larva attaches itself to the puparium by the tip of the abdomen and gnaws an entrance hole. A clear fluid is voided from the anus. De Wilde (1947) referred to this as an adhesive fluid that enables the larva to fasten itself to the puparium.

In all cases where a single attack was observed the hole gnawed by the larva was on the dorsum of the puparium and the hole was usually in a central position. When more than one larva entered a puparium, entrance holes were sometimes also found on the ventrum. The average size of an entrance hole is 0.125 mm. The process of gnawing the hole takes from 12 to 36 hours. The maximum of 36 hours does not cause a large number of the larvae to die before puparia are entered; the mortality for starved larvae at 36 hours was eight per cent. This is shown in Fig. 3 in the form of a curve of survival, calculated

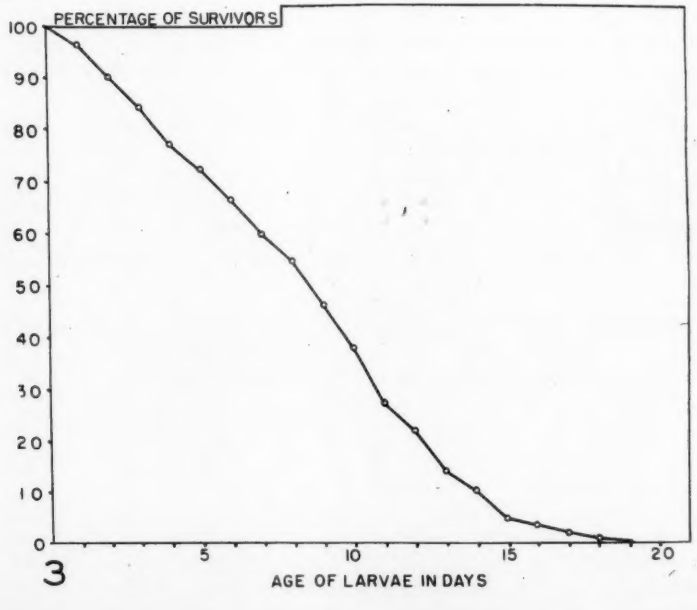

Fig. 3. Curve of survival for 306 starved first-stage larvae reared in stender dishes at 23.8°C.

from data on 306 larvae. Allee *et al.* (1947) referred to a curve of survival of this shape as the diagonal type, in which the death rates are approximately constant until old age is attained. The average span of life was 8.7 days.

The larva punctures the cuticle of the host pupa as it enters the puparium. This appears to be unavoidable, as the distance between the pupa, especially one that is newly formed, and the wall of the puparium is negligible. There is the possibility that the larva punctures the cuticle at this point to obtain nourishment, before moving to other feeding places, but in either case the end point is the same; the haemolymph wells out, coagulates, and effectively seals off the entrance hole. In effect the puparium is now a micro-habitat and the insect becomes adapted as a parasite for the remainder of its larval life.

The larva moves slowly over the pupa, puncturing the cuticle in many places, usually in the thoracic region. The punctures are seen as minute brownish spots. The larva becomes distended from feeding. At ecdysis it is always found on the mesothorax of the pupa with its head pointing to the cephalic end of the puparium. The first-stage larva, mature in eight days, determines the position to be occupied by the second stage. The first-stage larva overwinters within the puparium. First-stage larvae became active and fed on the host pupa within 24 hours after being removed from storage at O°C. for three months. Second- and third-stage larvae did not survive at this temperature.

When more than one first-stage larvae entered the puparium only one survived, the others dying soon after entering; the reason for this is unknown. The survivor usually completes its development. De Wilde (1947) stated that as many as five larvae of *A. bilineata* may be found within a puparium, but that only one comes to maturity.

The second-stage larvae bears little resemblance to the active, first-stage larva. The change in form indicates hypermetamorphosis. The larva is truly parasitic in appearance. The second-stage larva feeds through a small puncture on the vertex of the head of the pupa, with its body resting on the thorax. It does not move from this position and feeds steadily until ecdysis. At this point there is no apparent breaking down of the host pupa, and, apart from the minute brownish puncture marks, it is identical in appearance with an unparasitized pupa. The duration of this stadium is five days.

The third-stage larva, similarly changed in form, feeds very voraciously in the following manner. It feeds first on the head of the pupa, then on the thorax, and finally on the abdomen. At this point the larva is U-shaped, the head and thorax having moved caudally through an angle of 180°. The head now points toward the caudal end of the puparium. The head and thorax of the larva continue to move in this direction until its body is straight; by this time the whole of the pupa has been eaten except the cuticle, which is not consumed. This position is unaltered for 12 hours, and then a similar reverse movement commences, the head of the larva eventually pointing to the cephalic end of the puparium. The larva is mature in six days. After a quiescent period of 36 hours, moulting occurs, revealing the pupa; the cast skin adheres to the tip of the abdomen of the pupa. The pupal stage is completed within 14 days. The adult beetle emerges by gnawing an exit hole in the ventro-cephalic wall of the puparium.

Wadsworth (1915) described the manner in which the larvae of *A. bilineata* excrete. He stated that only minute drops of fluid are passed from the anus during feeding and that no other excretory matter is voided, but that two days

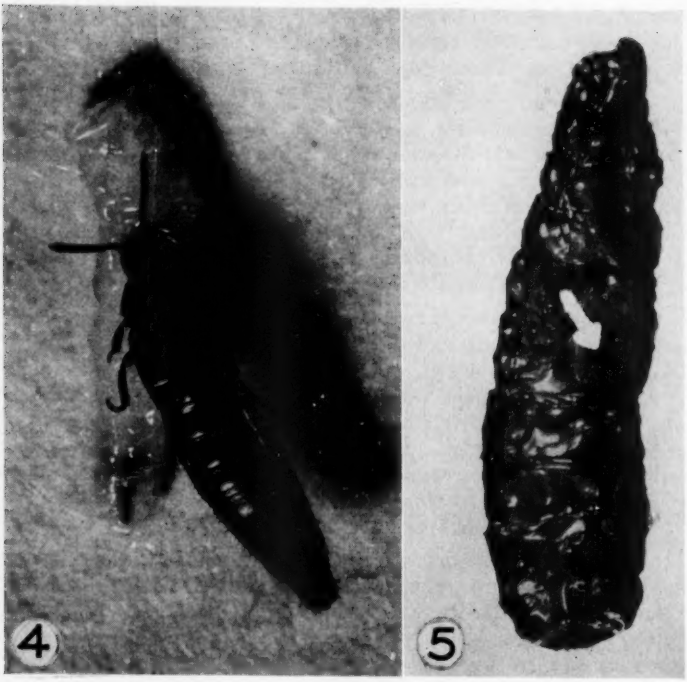

Fig. 4. A female of *Baryodma ontarionis* feeding upon a larva of *Musca domestica.*

Fig. 5. The remains of a larva of *Musca domestica* after having been fed upon by the beetles. The arrow indicates a feeding spot.

after feeding has ceased the larva excretes an opaque, semi-fluid, white substance, which is followed by darker-brown excretory matter. The larvae of *B. ontarionis* excrete in the same manner during feeding. The alimentary tract does not appear to be blind as in most hymenopterous parasites, as a gentle squeeze with fine forceps applied to the meconium will expel it from the first-, second-, and early third-stage larvae.

The respiratory systems of the second- and third-stage larvae are identical with that of the first-stage. Each possesses a single pair of thoracic spiracles, and one pair of spiracles on each of the first eight abdominal segments.

The predacious feeding habits of the adults were observed in the laboratory. Larvae of the following species were attacked and consumed: *Hylemya brassicae*, *Drosophila melanogaster*, *Musca domestica*, and *Pseudosarcophaga affinis* (Fall.). As many as five larvae of *H. brassicae* were consumed by an adult in a single day. It was noticed that the beetles preferred larvae to puparia. Puparia were attacked only when the daily quota of larvae was withheld. If larvae of the cabbage maggot are the source of food in the field, then the adults must be regarded as an important agency in the control of the host.

The act of feeding was observed on many occasions (Fig. 4). The beetles pierced the cuticle of the larvae with their mandibles and fed upon the juices by a combined lapping and sucking motion. The cuticle was not eaten (Fig. 5).

The beetles are cannibalistic. Those that had been fed attacked others savagely when the source of food was restricted. Starved adults only attacked and fed upon others that had died; however, in many instances dead beetles were not eaten. Eggs were eaten by the females. A female was observed to grasp an egg between her mandibles, pierce the chorion, and consume the contents. The chorion was not eaten. The average length of life of a female was 46.9 days in the laboratory; that of the male was 48.9 days.

Discussion

The larval forms of *B. ontarionis* in their adaptation to the parasitic mode of life show hypermetamorphosis. This seems to be true of other parasitic species of the Staphylinidae but species seem to vary in their degree of hypermetamorphosis. It is probably correlated with their degree of adaptation. Boving and Craighead (1931) considered that the characteristic changes or radical adaptations in the appearance of certain aleocharine larvae are brought about by an endo-parasitic, fungicolous, termitophilous, or myrmicophilous life.

B. ontarionis and *A. bilineata* have a campodeiform first-stage larva and eruciform second- and third-stage larvae. This is also true of *Aleochara* (*Polystoma*) *algarum* Fauvel, the adaptive characters of which were described by Lesne and Mercier (1922). The third-stage larva of each of these three species pupates within the host puparium. The first-stage larvae of *Aleochara curtula* Goetze and of *A. sparsa* are campodeiform, the second eruciform, and the third similar to the first. The larvae of the former were described by Kemner (1922) and those of the latter by Wright *et al.* (1947). The third-stage larva of *A. curtula* leaves the host puparium and pupates in the ground, but the pupal habitat of *A. sparsa* is unknown: Wright *et al.* (loc. cit.) could not find the pupal stage. Hence, it appears that *A. bilineata*, *B. ontarionis*, and *A. algarum* have a greater degree of hypermetamorphosis as they have become adapted to spending the whole of their larval and pupal lives within the puparium. *A. curtula* and *A. sparsa* have a lesser degree of hypermetamorphosis; and in the former, the pupal stage of which is known, the hypermetamorphosis corresponds with its degree of adaptation.

Summary

Baryodma ontarionis Casey and *Aleochara bilineata* Gyll., now thought to be conspecific, are parasites of the cabbage maggot, *Hylemya brassicae* (Bouché). *B. ontarionis* is prolific and is easily reared in the laboratory. The egg, larval, and pupal stages are described. The adults mate readily in the laboratory; the females require a pre-oviposition period of 48 hours. In the laboratory the females show no preference for laying eggs on or near puparia of the cabbage maggot. The daily average number of eggs laid per female is 15. Seventy-six per cent of the eggs hatched on the fifth day. Immediately after eclosion, the larva is active and free-living; it requires a period of 12-36 hours to gnaw an entrance hole into the puparium. The entrance hole is sealed with the haemolymph of the pupa. At 36 hours the mortality of starved first-stage larvae is eight per cent; the average span of life of starved larvae is 8.7 days. More than one larva may enter a puparium but only one reaches maturity. The first-stage larva overwinters within the host puparium. The second- and third-stage larvae feed upon the host pupa in a definite cycle. The duration of the larval period is 20.5 days; and of the pupal period, 14 days. The larvae show hypermetamorphosis. The adults prefer larvae to puparia for food. In the laboratory the average life span of females was 49 days and that of males was two days less. The adults are predacious and cannibalistic.

Acknowledgments

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Note on Preliminary Field Trials of a Bacterium to Control the Codling Moth

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A bacterium, *Bacillus cereus* F. and F., which was isolated from diseased larvae of the codling moth, *Carpocapsa pomonella* (L.), is pathogenic to the codling moth in laboratory experiments (Stephens, 1952).

A series of trials was set up at Kentville to test the effectiveness of this bacterium against codling moth larvae in the field. *B. cereus* spores were propagated according to the method of Reed and McKercher (1948) and shipped to the field as spore suspensions.

Artificially established codling moth populations were sprayed with two different spore suspensions. Lot A was produced after three serial passages through codling moth larvae and was applied at a concentration of 1.4×10^9 spores per millilitre; lot B, produced after nine serial passages, was applied at a concentration of 3.5×10^9 spores per millilitre.

The survival of the populations was reduced to 39.4 per cent after treatment with lot A and to 15.5 per cent after treatment with lot B, as compared with a survival of 48.8 per cent in the check population; this reduction in survival is significant. The decreased survival was a result of infection of the larvae by the bacterium, which was isolated from all dead larvae found.

The results warrant further investigation.

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A Two-Year Life-Cycle in Grasshoppers (Orthoptera: Acrididae) Overwintering as Eggs and Nymphs[1]

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Introduction

Most grasshoppers of the prairie region of Western Canada hatch in the spring and complete their life-cycles in one year. There are a few species, however, that hatch in the fall and overwinter as partly grown nymphs; these include the oedipodines *Arphia conspersa* Scudd., *Pardalophora apiculata* (Harr.), *Xanthippus corallipes latefasciatus* Scudd., and *Chortophaga viridifasciata* (Deg.) and the acridine *Psoloessa delicatula delicatula* (Scudd.). Criddle (1933) suggested this when he stated that, although the eggs of some Oedipodinae that hibernate as nymphs normally hatch within a month or two after oviposition, they occasionally fail to do so, in which case a further period of 12 months may occur before hatching takes place. The life-histories of all these except *C. viridifasciata* were studied.

Methods

Field observations and collections were made in the Pike Lake region of central Saskatchewan, where these species of grasshoppers were present in varying numbers.

Nymphs of each species were collected in the spring of 1950, placed in field cages 2 by 2 by 2½ feet, and reared to the adult stage. The eggs subsequently laid during early July were carefully sifted from the soil and placed in salve tins containing moist sand. Some of the eggs were then placed in a constant temperature cabinet at 82°F. Others were kept at 30°F. for varying periods, or in soil outdoors, to be incubated later in the constant temperature cabinet. A number of eggs were left outdoors until hatching occurred. The eggs left in soil outdoors were subjected to temperatures as high as 75°F. during the summer, and to below-freezing temperatures from the beginning of November for about four months.

Nymphs of *Pardalophora apiculata* were collected also in the spring of 1951 and reared in outdoor cages as mentioned above. The eggs subsequently laid were placed in soil outdoors. At monthly intervals, 10 of these eggs were brought into the laboratory and incubated at 82°F. In February, 1952, a few of the unhatched eggs from each monthly group were examined for embryological development by the methods outlined by Slifer (1945) and Salt (1949).

Nymphs were also collected in the late fall and early spring to determine the instar in which each species overwintered. In addition, cages containing different nymphal stages of each species were set outdoors in the fall in order to facilitate the study of hibernation in these insects.

The nymphs that hatched during the incubation experiments were reared in the laboratory at 82°F. and were fed on young wheat seedlings and lettuce.

Results

Field observations revealed that the seasonal histories of these grasshoppers are basically similar. After hibernating, the nymphs resume activity during the latter part of April and become adults during the first part of May. Egg-laying takes place in June and early July, and by the middle of July most of the adults have disappeared. The eggs hatch in August and early September of the second

1Contribution No. 2985, Division of Entomology, Science Service, Department of Agriculture, Ottawa, Canada. A portion of this study was presented to the Graduate School of the University of Saskatchewan in partial fulfilment of the degree of Master of Science.
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year; the nymphs usually hibernate in the fifth stage. *Psoloessa delicatula*, followed closely by *Arphia conspersa*, is the first species to become active in the spring. These are followed by *Xanthippus latefasciatus* and *Pardalophora apiculata* in that order. The time of first appearance varies with seasonal conditions, but usually occurs after a few warm days in the spring, with temperatures reaching 60° to 65°F.

The field collections in the late fall and early spring, and the hibernation studies of nymphs in outdoor cages during the winter, showed that all four species usually pass the second winter in the fifth instar. Overwintering was common in the third and fourth instars, but was never found to occur in the first or second instars, or in the adult stage.

The limited rearing of grasshoppers in the laboratory showed that nymphs of *Arphia conspersa* that hatched on December 22 developed normally until January 30, when the fourth instar appeared. No further moulting occurred, although the nymphs remained alive for several weeks, the last remaining one dying on March 12. Nymphs of *Pardalophora apiculata* that hatched on July 19 developed normally until August 28, when the third moult occurred. One specimen remained in this stage until it died on November 16, and another remained without moulting until January 1, when it also died. In a later experiment one specimen of *P. apiculata* remained alive in the third instar for more than three months without moulting. On the other hand, *Xanthippus latefasciatus* was reared successfully from egg to adult in approximately two months with no apparent cessation in development.

Psoloessa delicatula and *Arphia conspersa* pass through five nymphal stages and *Pardalophora apiculata* passes through six; *Xanthippus corallipes* has five nymphal stages in the male, and six in the female.

Incubation of Eggs

As shown in Table I, eggs of *A. conspersa* were the only ones that hatched when placed in incubation at 82°F. soon after oviposition. These hatched after incubation for 23 to 27 days.

TABLE I

Incubation Periods and Numbers of Eggs Hatching when placed at 82° F. shortly after Oviposition in early July, 1950

Species	Eggs placed in Incubation		Eggs Hatched		
	Approx. Number	Date, 1950	Number	Date, 1950	Days in Incubation
Pardalophora apiculata	40	July 8	0	—	—
P. apiculata	40	July 19	0	—	—
Arphia conspersa	25	July 8	22	July 30–31	23–24
A. conspersa	25	July 19	15	Aug. 11–14	24–27
Xanthippus latefasciatus	40	July 8	0	–	–
X. latefasciatus	40	July 19	0	–	–
Psoloessa delicatula	10	July 8	0	–	–

Eggs of *A. conspersa* were also the only ones that hatched when, shortly after oviposition, they were placed at 30°F. for four or five months and then incubated at 82°F. Those that hatched did so after 22 to 26 days' incubation (Table II).

TABLE II

INCUBATION PERIODS AND NUMBERS OF EGGS HATCHING WHEN PLACED AT 82° F., AFTER HAVING BEEN KEPT AT 30° F. FROM TIME OF OVIPOSITION IN EARLY JULY, 1950.

Species	Eggs placed in Incubation		Eggs Hatched		
	Approx. Number	Date, 1950	Number	Date, 1950	Days in Incubation
Pardalophora apiculata	40	Nov. 7	0	–	–
P. apiculata	80	Dec. 1	0	–	–
Arphia conspersa	25	Nov. 7	0	–	–
A. conspersa	50	Dec. 1	12	Dec. 22–26	22–26
Xanthippus latefasciatus	10	Nov. 7	0	–	–
Psoloessa delicatula	5	Nov. 29	0	–	–

Observations on the unhatched eggs indicated in Tables I and II were discontinued on April 7, 1951, when most of the eggs had perished.

Eggs of all species except *Psoloessa delicatula* hatched when, after exposure to outdoor conditions for five months or longer from the time of oviposition, they were placed in incubation at 82°F. In the laboratory, incubation periods for the eggs that hatched varied from 18 to 27 days (Table III).

TABLE III

INCUBATION PERIODS AND NUMBERS OF EGGS HATCHING AT 82° F. AFTER EXPOSURE TO OUTDOOR CONDITIONS FOR FIVE MONTHS OR LONGER FROM TIME OF OVIPOSITION IN EARLY JULY, 1950

Species	Eggs placed in Incubation		Eggs Hatched		
	Approx. Number	Date	Number	Dates	Days in Incubation
Pardalophora apiculata	40	Dec. 9, 1950	7	Dec. 29-32, 1950	21–22
P. apiculata	25	Apr. 26, 1951	11	May 22-23, 1951	27–28
Arphia conspersa	50	Dec. 8, 1950	25	Dec. 23-26, 1950	16–19
A. conspersa	50	Apr. 23, 1951	16	May 14-18, 1951	22–26
Xanthippus latefasciatus	50	Dec. 9, 1950	39	Dec. 29, 1950,– Jan. 8, 1951	21–31
X. latefasciatus	30	Jan. 13, 1951	28	Feb. 1–5, 1951	20–24
X. latefasciatus	50	Apr. 7, 1951	41	Apr. 25–May 2, 1951	19–26
Psoloessa delicatula	25	Jan. 13, 1951	0	–	–

TABLE IV

INCUBATION PERIODS AND NUMBERS OF EGGS HATCHING WHEN KEPT OUTDOORS CONTINUOUSLY FROM TIME OF OVIPOSITION IN EARLY JULY, 1950

Species	Eggs Incubated	Eggs Hatched		
	Number	Number	Dates, 1951	Months Outdoors
Pardalophora apiculata	106	56*	Aug. 2–3	13
Arphia conspersa	113	80*	Aug. 2–3	13

*The remainder of the eggs were fully developed, and no doubt would have hatched in a short time if they had been left undisturbed.

Eggs of *Pardalophora apiculata* and *Arphia conspersa* that remained outdoors from the time of oviposition in July, 1950, until the following summer hatched in about 13 months. Eggs of *Xanthippus latefasciatus* and *Psoloessa delicatula* remained outdoors in a viable condition until the following spring, when they were removed for incubation in the laboratory. None of the eggs of these four species that were left outdoors hatched during the summer in which they were laid (Table IV).

Table V indicates that eggs of *Pardalophora apiculata* incubated at 82°F. will hatch only if they have been exposed to summer and early winter conditions for four to five months. Forty per cent of the eggs remaining at the end of this experiment on February 3 were non-viable or had perished. Examination of a few viable, unhatched eggs from each monthly incubated group revealed that development in all eggs had reached the stage just before blastokinesis.

TABLE V

INCUBATION PERIODS AND NUMBERS OF EGGS HATCHING WHEN PLACED AT 82 F. AT MONTHLY INTERVALS, AFTER EXPOSURE TO OUTDOOR CONDITIONS FROM TIME OF OVIPOSITION IN JULY, 1951

Species	Eggs placed in Incubation		Eggs Hatched		
	Date	Number	Number	Date(s)	Days in Incubation
Pardalophora apiculata	Aug. 3, 1951	10	0	–	–
P. apiculata	Sept. 4. 1951	10	0	–	–
P. apiculata	Oct. 1. 1951	10	0	–	–
P. apiculata	Nov. 1, 1951	10	2	Nov. 30–Dec. 1, 1951	30–31
P. apiculata	Dec. 1, 1951	10	1	Jan. 1, 1952	32
P. apiculata	Jan. 2, 1952	10	3	Jan. 28–Feb. 3, 1952	27–33
P. apiculata	Feb. 1, 1952	10	2	Feb. 26, 1952	26

Discussion

The results indicate that *Pardalophora apiculata* and *Xanthippus latefasciatus* have two-year life-cycles in central Saskatchewan. Because not one egg of these species hatched outdoors during the summer in which it was laid, or indoors at a constant temperature of 82°F. beginning shortly after oviposition, a diapause is indicated. Lack of moisture could not have imposed a resting period in development under laboratory conditions, as it might under natural midsummer conditions. The diapause can be broken by exposure to freezing conditions, such as occur in Saskatchewan during the winter, but only after the eggs have first been exposed to temperatures high enough to permit development to some stage which has not been determined. Table II shows that exposure to freezing temperatures from time of oviposition for several months did not break the diapause in eggs of these two species. Diapause, at least in eggs of *P. apiculata*, apparently occurs just before blastokinesis.

The rearing of nymphs from eggs hatched in the laboratory suggests a diapause also in the nymphal development of some of these species, but more evidence is needed to corroborate this.

The results indicate that the life-cycle of *Arphia conspersa* may be completed in one or two years. As shown in Table IV, none of its eggs hatched outdoors during the summer in which they were laid, and as nymphs emerging from these eggs did not reach maturity until the following spring this species

apparently has a two-year life-cycle under conditions in central Saskatchewan. But Table I indicates that many of the eggs hatched when incubated without previous exposure to low temperatures; this suggests that diapause is not obligatory and that, if eggs of this species are exposed under natural conditions to sufficient day-degrees of temperature, they may hatch during the summer in which they are laid. Therefore, in seasons with high temperatures during early spring the overwintered nymphs may develop rapidly to maturity, and the adults may lay their eggs early in the season. With sufficiently high temperatures throughout the summer, hatching could theoretically occur in late summer, so that the life-cycle might be completed in one year. Although no confirmation is available, this is probably what takes place in the more southerly parts of its range.

No definite conclusions can be drawn from these studies concerning *Psoloessa delicatula* because none of its eggs hatched under any of the treatments. However, this species probably also has a two-year life-cycle in central Saskatchewan, because its eggs apparently remained viable outdoors throughout the summer in which they were laid.

The diagrammatic comparison of the seasonal histories of *Pardalophora apiculata* and *Melanoplus mexicanus mexicanus* (Sauss.) (Fig. 1) raises the question why, after overwintering under natural conditions, eggs of the species that hibernate in the nymphal stage should hatch over two months later than those of the common economic species. A higher developmental zero or a slower rate of development may be the factor responsible.

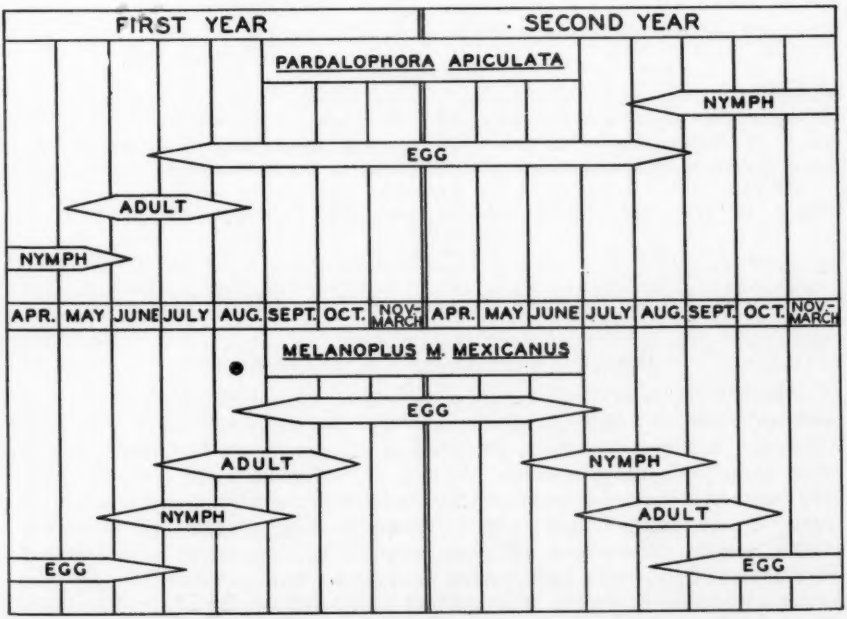

Fig. 1. Comparison of seasonal histories of a grasshopper with a two-year life-cycle and a species with a one-year life-cycle.

It is concluded that under conditions such as are found in central Saskatchewan all species of grasshoppers that hibernate as nymphs normally undergo a two-year life-cycle. This life-cycle may be summarized as follows: Oviposition usually occurs in June and early July; the eggs overwinter, hatching the following August. The nymphs develop to one of the later instars (most commonly the fifth), in which stage the second winter is passed. Early the following spring activity is resumed and development proceeds rapidly to maturity.

Summary

Five species of Acrididae overwinter in the nymphal stages in Saskatchewan; four of these are discussed in this paper. Incubation experiments indicate that these usually have a two-year life-cycle in central Saskatchewan. They pass the first winter in the egg stage and the second in one of the later nymphal stages.

Diapause appears to be obligatory in eggs of *Pardalophora apiculata* and *Xanthippus latefasciatus*, but probably not in those of *Arphia conspersa*; no eggs of *Psoloessa delicatula* hatched in incubation. A diapause may also occur in the nymphal development of some of the species.

Acknowledgments

The writer expresses his sincere appreciation for the encouragement and advice given by the late Mr. H. W. Moore, who suggested the problem. Acknowledgment is gratefully made to Dr. J. G. Rempel, Department of Biology, University of Saskatchewan, who supervised the investigation. Sincere thanks are extended to Dr. A. P. Arnason, Officer-in-Charge of the Field Crop Insect Laboratory, Saskatoon, and all members of the staff, especially Mr. L. G. Putnam, and to Mr. A. R. Brooks, Systematic Entomology, Division of Entomology, Saskatoon, whose advice was available at all times.

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Plastic Embedding of Insects—A Simplified Technique

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Methods for preserving biological material in transparent plastics were first published some 15 years ago (Hibben, 1937), and have now come into quite wide use. Accounts have been published of several suitable techniques, mostly rather similar, in both the scientific (Knight, 1937; Puckett, 1940, 1941; Raizenne, 1949) and the commercial literature (Sheehan & Stewart, 1947; General Biological Supply House, 1950; Ward's, 1947). Although these materials are peculiarly suitable for the preservation of insect material, only one short mimeographed publication (Silver, 1948), has appeared describing a method specifically designed for use with an insect group. This method is essentially similar to the procedures described for soft tissues, all of which are much more elaborate than is necessary for insect material. Sheehan and Stewart (1947) mention that dried insect material may be immersed directly in the plastic monomer in the process which

they describe. Details of the method described here have been developed at the University of Alberta and used successfully with arachnid material, and with material of the following insect orders: Orthoptera, Odonata, Homoptera, Coleoptera, Lepidoptera, Diptera, and Hymenoptera. Specimens treated in this way are cleared to a degree similar to those mounted in balsam or euparal, so that colours appear somewhat dark and surface detail may be difficult to see, but they may be examined by transmitted light and internal structures may be seen. They are completely visible from every angle and are almost indestructible, which makes them invaluable for introductory courses and display purposes. Figure 1 shows a group of specimens preserved in this way, and figure 2 shows the detail which can be seen by examination under a low power monocular microscope.

Several proprietary materials are available from biological supply houses. The first materials used were methyl and ethyl methacrylates. Most of those now in use are unsaturated polyester resins, sold in the monomer form with an appropriate catalyst such as tertiary butyl hydroperoxide, which accelerates polymerization. They are clear, colourless, rather viscous liquids, which keep quite well if stored in the dark at low temperatures. For use with insects, there is little to choose between the available varieties.

Equipment and Supplies Required

The only special equipment needed is a vacuum pump and vacuum desiccator, and shallow, flat-bottomed glassware of the Pyrex type. Domestic items such as pie dishes and the rectangular lids of refrigerator sets have been found more suitable than anything made for laboratory purposes. In selecting rectangular dishes care must be taken that the sides have no inward curve to them; if they have, they are usually broken by the shrinkage of the plastic. A manometer to indicate the degree of vacuum reached is useful. Small carbon filament lamps are also useful in the setting process.

A supply of the plastic monomer and a suitable catalyst is of course needed, and also of the following polishing materials: waterproof emery paper of grades 100, 240, and 600; tripoli powder and soft felt, levigated alumina and pile polishing cloths. Most of these materials or suitable substitutes are available in metallurgical laboratories, together with power equipment for using them.

Procedure

Freshly killed insects are most suitable, or failing this they may be preserved in an alcohol-glycerine mixture so that they can be readily set in the attitude desired. This may be done either by fixing the tarsi on cork with crossed pins, using suitable supports for the wings, or by fixing them on to glass microscope slides with a wax or cement which can readily be removed with a solvent. If the humidity is low they may simply be allowed to dry in the air in this attitude, otherwise it is preferable to store them over calcium chloride in a dessicator for a few days.

Embedding

A thin supporting layer of catalysed plastic is poured into a pyrex dish and allowed to set, while a batch of dried insect specimens is placed in a second container of uncatalysed plastic and put under vacuum. A piece of heavy gauge ¼" mesh wire gauze cut to fit inside this second container is useful to ensure that specimens remain submerged. Vacuum should be applied gradually, the pressure being reduced to 2-3 mms. of mercury and held there for a few minutes, when pressure should be gradually restored. This procedure is repeated three or four times, until all specimens sink in the plastic. With some beetles

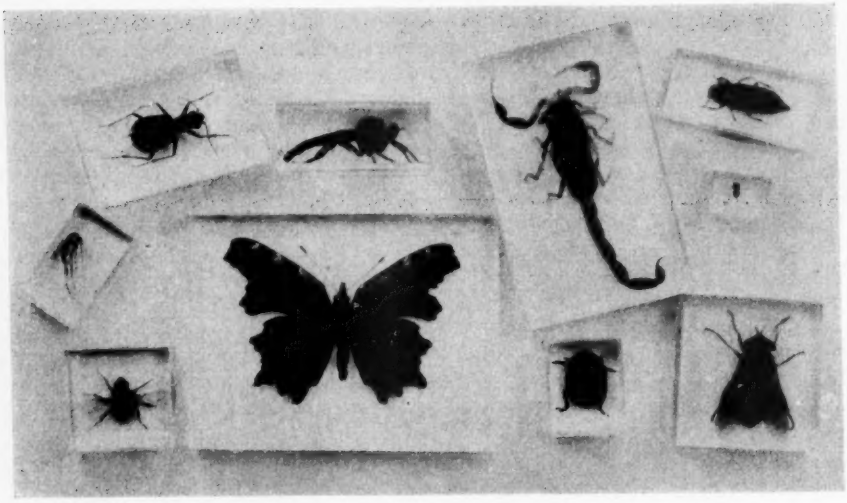

Fig. 1. A group of plastic embedded specimens. X ½.

and other highly sclerotized insects it may be necessary to turn them over between evacuations. The specimens are then transferred to their required postions on the catalysed plastic, which by this time will usually have set to a jelly-like consistency. A section lifter and a mounted needle are the best tools for this task; uncatalysed plastic should be allowed to drain from them as far as possible. The viscosity of the monomer makes handling somewhat difficult at this stage, but the insects are now more pliable than when just dried, and minor adjustments of position can be made. More catalysed plastic is then poured into the dish until the level rises a mm. or so above the top of the specimens. Air bubbles which fail to rise and burst within a few minutes may be disposed of with a heated needle.

The final processes of cutting and polishing may be eliminated altogether, or at least reduced to a minimum, if individual moulds are constructed from glass slides, shell vials, or tubing. This procedure has been described by Patterson (1947), Silver (1948) and others. The first author also reviews the literature on plastic embedding.

Setting

This process should be carried out as slowly as possible. The rate at which it proceeds is dependent on the temperature, but since heat is evolved by the process itself, it also depends on the dimensions of the mass, the nature of the surrounding materials, and the amount of ventilation. The proportion of catalyst also affects the rate of setting; most suppliers suggest a range of catalyst proportions dependent on the thickness of the block to be cast. With insects embedded in this way the absolute minimum of catalyst should be used. Too rapid setting results in the cracking of large and thick blocks, and encourages the formation of a thin silvery film over parts of the specimens resulting from the separation of the plastic from the surface of the specimen. This latter trouble is particularly difficult to avoid with some species, especially beetles, and it may make its appearance at any time during the first two or three days after pouring. The material shrinks slightly as it sets; this means that the blocks will

usually fall out of the dishes when they are set, at the same time it seems to play a part in the formation of the silvery film. If heat is applied by conduction there is a tendency for the outer layers of the block to harden first, so that the inner layers around the specimens are in a state of tension as they set, and tend to pull away from the specimens. Radiant heat, on the other hand, is absorbed more heavily by the specimens than by the plastic, so that heating and setting proceed from within outwards. The procedure which has been found most satisfactory is to place the dish on a metal grid, such as an oven shelf, so that air can circulate on all sides, and arrange an 8 c.p. carbon filament lamp about a foot above this. Under these conditions the material will become hard in a day or two. The subsequent processes of cutting and polishing are more easily carried out, however, if the blocks are allowed to mature for at least a week.

Cutting and polishing

Almost any fine-toothed saw is suitable for cutting the individual specimens out of a block. A band saw provides the easiest method, but it can also be done by hand with a hack saw or tenon saw. The remaining processes of shaping and polishing are best done in the wet state. They too may be done by hand, or it is a simple matter to fit a metal disc for holding circles of emery paper on to

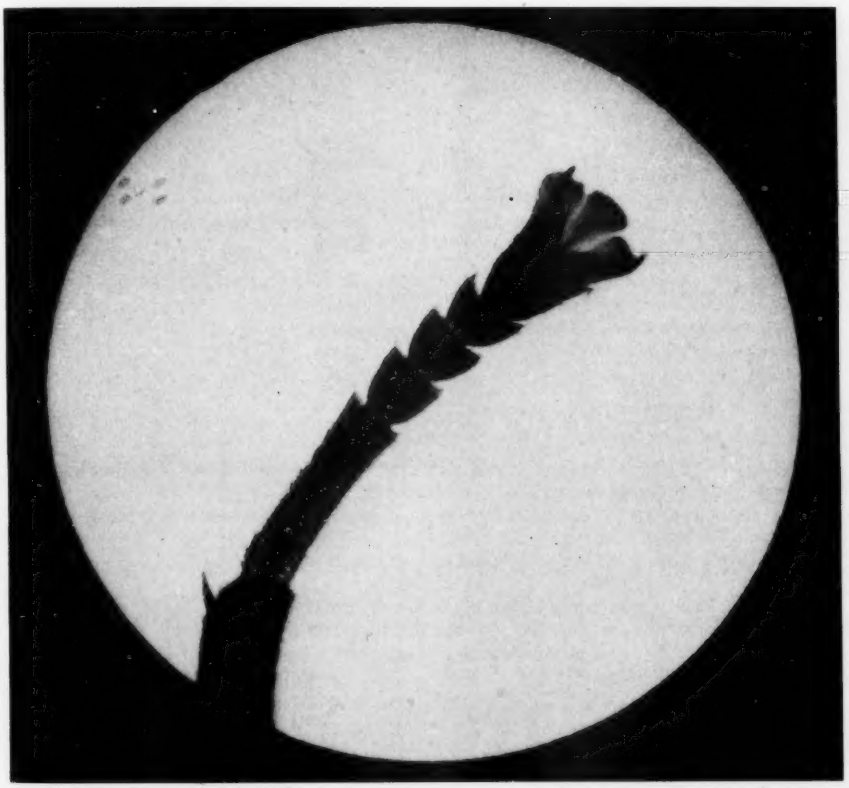

Fig. 2. Front tarsus of a tabanid. Photomicrograph from a specimen embedded in plastic. X 28.

the pulley of the motor used for driving the vacuum pump. Cutting speeds should range from about 1200 f.p.m. for the first processes to 400 f.p.m. for the final polishing. A guide is helpful in getting the faces of the blocks at right angles to each other; this should be done, and any adjustments to the size and shape of the block made with the 100 grade emery. The marks made by this are then removed by working in a direction at right angles to them with the 240 grade. It is also advisable at this stage to put a slight bevel on all the edges which otherwise cause heavy wear and may tear the 600 grade paper and the polishing cloths. The 600 grade paper is then used to remove the marks made by the 240 grade, and the block is ready for polishing. It is, of course, necessary to remove all traces of each earlier abrasive before proceeding to the next; for this reason much time is saved if a large number of specimens is processed at a time.

Polishing can be carried out directly from 600 grade emery with levigated alumina on a pile polishing cloth. This is rather tedious, especially if it has to be done by hand, and time will be saved by using tripoli powder on a soft felt first. Both processes are carried out wet, and they are also used for repolishing mounts which have become scratched. This only seems necessary at long intervals; specimens in use for three years do not yet require it. Completed sets of specimens can be conveniently stored in transparent plastic boxes. Labelling can best be accomplished in india ink on a portion of one of the lateral faces previously roughened with 600 grade emery. The lettering may then be protected with varnish. Alternatively labels may be embedded in the plastic with the insect.

Acknowledgments

I am indebted to V. J. Campbell and Margaret V. Baines, who did much of the work on which the development of this method was based, and are responsible for some of its features.

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The Tachinid Parasites of *Archips cerasivorana* Fitch. (1) *Dichaetoneura leucoptera* Johns. (Diptera)

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The Tortricid *Archips cerasivorana*, described in 1856 by Fitch and usually known by the rather cumbersome name of the Cherry-Tree Ugly Nest Tortricid, is a well known insect, widely distributed in the United States and Canada. Its life-history and habits are described in many of the standard textbooks. The account given is usually rather vague but a more complete and satisfactory treatment is to be found in a paper published by A. B. Baird in 1918. The insect hibernates in the egg stage. The eggs hatch in the latter part of May and during early June. The larvae construct a web which they gradually extend over the foliage on which they feed. In the web they construct silk lined cells in which they live individually when not at work. They are full grown by about the middle of July or later. Their principal food plant is the choke-cherry but occasionally they attack the cultivated cherry.

Over a dozen species of parasites have been recorded from *Archips cerasivorana*. Of these the most interesting is the curious Tachinid *Dichaetoneura leucoptera* Johns. The Tachinids listed for this host in the Parasite Catalogue of the Commonwealth Institute of Biological Control are as follows:—

Dichaetoneura leucoptera Johns,
Nemorilla maculosa Meig.
Phorocera tortricis Coq.
Phytomyptera leucoptera Johns.
Schizocerophaga leibyi Tns.
Zenillia blanda O. S.
Zenillia boarmiae Coq.

Of these the first and fourth are the same. *Zenillia boarmiae* Coq., recorded by Baird under the name of *Exorista boarmiae*, has until recently been confused with *Zenillia blanda* (vide Sellers, 1943) and does not really appear to be a parasite of *cerasivorana*. *Schizocerophaga leibyi* Tns. is a common and important parasite of the sweet potato sawly *Sterictiphora cellularis* Say. The record from *cerasivorana* is based on the work of C. H. Hoffmann (1936) but he reared only one specimen of this parasite from a very large collection of nests made in eastern Minnesota. He did not definitely prove that *Schizocerophaga* is a parasite of *cerasivorana* and it seems probable that a sawfly larva infested by the parasite was accidentally introduced with the material. The other records appear to be authentic. In fact the Canadian National Collection contains specimens of *Dichaetoneura laucoptera*, *Phorocera tortricis* and *Zenillia blanda* reared from *cerasivorana*. Specimens of the species listed above as *Nemorilla maculosa* reared from the same host are also in the collection under the name *Nemorilla pyste* Walk.

The adults of the Tachinid parasites of *cerasivorana* can be separated by the following key.

(1) Fourth vein evanescent beyond the bend; eyes bare ..... *Dichaetoneura leucoptera* Johns.
Fourth vein complete; eyes hairy 2
(2) Facial ridges bristled on lower three-fifths ..... *Phorocera tortricis* Coq.
Facial ridges bristled on lower half or less 3

(3) Third antennal joint over four times as long as second; abdomen wide and deep; three humeral bristles.....*Zenilla blanda* O.S.
Third antennal joint only slightly longer than second; abdomen flattened; five humeral bristles.....*Nemorilla pyste* Walk.

The developmental stages including the puparia in so far as they are known will be described in this and following papers. However a key to the puparia may conveniently be given at this point. It is as follows.

(1) Spiracular slits serpentine; anterior spiracles with two, rarely three respiratory papillae; prothoracic cornicles present.....*Zenilla blanda* O.S.
Spiracular slits straight—2.
(2) Prothoracic cornicles present; anterior spiracles absent; a pale protuberance below posterior spiracles, prolonged between them—*Phorocera tortricis* Coq.
Prothoracic cornicles absent; no protuberance below posterior spiracles—3.
(3) Posterior extremity rounded; posterior spiracles almost terminal; median slit ventro—laterally directed; 8 or 9 anterior respiratory papillae arranged in an open ring.....*Dichaetoneura leucoptera* Johns.
Posterior extremity subconical, posterior spiracles above the bilateral longitudinal axis; median slit dorso-pleurally directed; anterior spiracles with 10 to 12 respiratory papillae scattered over the surface.....*Nemorilla pyste* Walk.

The four Tachinid parasites of *cerasivorana* are not very closely related taxonomically. The life-history and systematic relationships of these species will therefore be treated separately.

Dichaetoneura leucoptera Johns.
Larval Stages

Stage I (length 1.01 mm., width 0.3475 mm.)

The only stage I larvae available for description have evidently grown somewhat since hatching, so that the groups of cuticular plates in certain areas are more widely separated than in newly hatched specimens. The general structure of the primary larva is unusual and of a type not mentioned by Townsend in the "Manual of Myiology", though it is clear that a vast amount of material passed through his hands. The main structural features may be summarized as follows: (Fig. 1) the dorsal area is composed of a large number of narrow slightly overlapping plates which are only feebly pigmented but very resistant, persisting in the host pupa even after the adult has issued; the pleural area, at least in the abdominal segments, bears on each side a dorso-pleural and a medio-pleural band of faintly pigmented, polygonal plates and a smaller, less clearly differentiated ventro-pleural group; finally, one or two bands of minute spines traverse the intersegmental conjunctivae in the ventral region.

The antenna (length 0.0084 mm.) is cylindrical (Fig. 13) with a distinct basal collar, rounded at the end, about three times as long as its diameter; near it is a small clavate sensorium which appears to be bent downward, as in *Dexia* and related forms; the dorsum of segment I is covered with moderate sized, faintly pigmented, overlapping plates which are short and rounded near the anterior border of the segment, more or less triangular in the median area and have the form of narrow laterally elongate bands irregularly toothed on the free margin, toward the posterior border; across the anterior third of the segments runs a ventral band of small, narrow scale-like spines comprising 3 or 4 rows in the pleural region but broadening somewhat in the mid-ventral area. In segment II the arrangement is somewhat similar; the dorsal and dorsopleural regions are covered with overlapping plates, forming about 10 rows; the plates near the

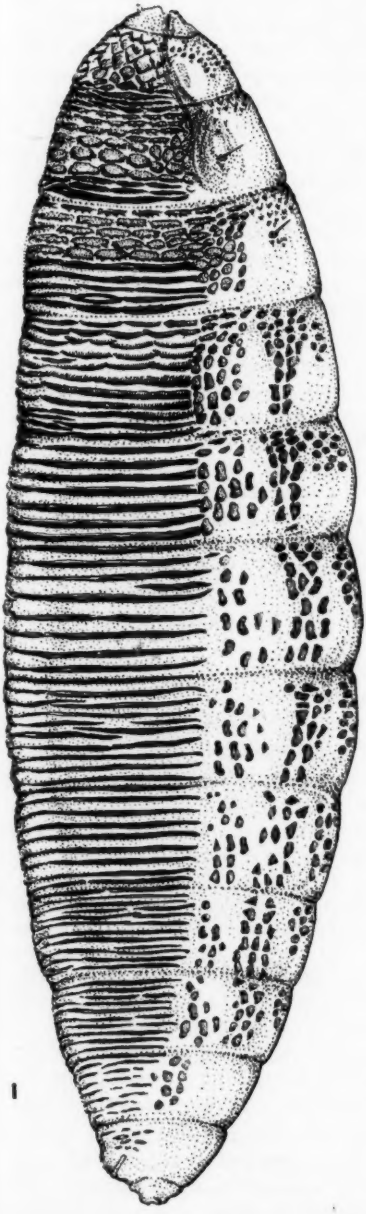


PLATE I

Dichaetoneura leucoptera Johns.: Fig. 1, larva, stage I, dorso-lateral view; 2, buccopharyngeal armature, stage I; 3, female reproductive system, showing ovaries, spermathecae, accesory glands and uterus.

anterior border are small, oblong in form, the free margin bearing small teeth, the median plates rounded or sub-triangular, the plates of the last three rows elongating laterally with a practically continuous narrow band along the intersegmental conjunctiva; a band comprising 3 or 4 rows of small plates, usually toothed posteriorly, extends across the ventro-anterior margin of the segment. In segment III the dorsal area bears, near the anterior border, a row of very narrow plates, and behind this 4 or 5 rows of broader elements, those of the middle rows toothed on the free margin; behind these are 4 narrow, overlapping, laterally elongate continuous plates; at the pleural ends of these plates, however, are some roughly oblong, separate elements; across the anterior margin of the segment run 3 or 4 rows of small plates, toothed posteriorly; this band is prolonged backward about halfway across the segment at each end; a short row of minute, nodule-like spines also traverses the midventral area. Segment IV has about 10 narrow overlapping dorsal plates, the anterior 4 or 5 being more or less broken up into separate elements; immediately adjacent to the ends of the plates is a dorso-pleural group of more or less oblong plates in 3 longitudinal rows; separated from this by an interval of bare cuticle, is another similar group, to which is attached near the ventro-anterior angle a small group of small plates; between this and the corresponding group on the other side of the body, along the anterior ventral margin, runs a single row of small, strongly hooked spines. Segments V and VI are similar to IV but the anterior dorsal plates are undivided while the ventro-pleural group of plates is more distinct and longer, about half the length of the segment in V and three-fourths in VI; the row of spines along the anterior ventral margin of VI is doubled in the middle by a short row of small elements, directed forward, on the posterior margin of V; on the posterior margin of VII is a similar row extending right across the segment parallel to the row on the anterior border of VII. Segments VII to X inclusive are essentially similar in form. Segment XI, which bears the posterior spiracles and the anal plate, bears the usual plates on the anterior dorsal half but these break up into separate elements posteriorly; the dorso-pleural and medio-pleural groups of plates are present but the ventro-pleural group is absent; in addition to the spine row on the anterior ventral margin, there is a second row traversing the ventral area about the level of the anal plate, a double or triple row near the posterior extremity and some scattered spines in front of the ends of these rows; the anal plate is oval, situated near the anterior margin of the ventral region. The posterior spiracles (Figs. 11, 12) open on the dorsal area some distance in front of the tip of the segment; the felt-chambers (length, 0.034 mm.) are 5 to 6 times as long as their diameter.

The buccopharyngeal armature (Fig. 2) (length, 0.126 mm.) is rather stout, with no articulations, brown in colour, somewhat similar in its general form to that of *Nemoraea pellucida* Meig. (vide Thompson '23), though the larvae of the two species are otherwise dissimilar; the anterior region is gently curved and acuminate, almost as long as the intermediate and posterior regions together; its under side is weakly toothed or transversely ridged about the middle; the intermediate region is rather stout, its upper surface slightly concave, about as long as the dorsal wing of the posterior region which is short and rounded posteriorly; the intra-alar space is acute or slightly rounded anteriorly; the ventral wing is short and broad, about two-thirds as long as the dorsal wing, with a semicircular notch in its posterior border; above the base of the ventral wing there is a vague dark circular area in some specimens, reaching almost to the dorsal edge of the posterior region; the anterior lateral plates are elongate, each with a circular

sensorium near the anterior end; the sclerite of the salivary gland is narrow, distinctly separated from the intermediate region.

The cuticular sensoria differ somewhat in form, number and arrangement in the different parts of the body. On the dorsum of the thorax there is a row of 5 circular sensoria across the middle of each segment; a short distance from the outer end of the row, on each side, is a pair of circular sensoria lying along an antero-posterior line, one slightly anterior to the level of the transverse row, the other behind it; these constitute the dorso-pleural group; some distance ventrad of this group is an elongate spine. (length, 0.0168 mm.) tapering to an acute point; slightly in front of this and a little ventrad, is a circular sensorium and another about twice as far behind it and also a little ventrad; a little ventrad of the second sensorium is a third so that the pleuro-ventral group forms a triangle with the spine in the middle; a fourth circular sensorium lies further ventrad in a line with the second and third; additional ventral sensoria are probably present but could not be seen in my specimens. On the abdominal segments the dorsal row is composed of four circular sensoria; the dorso-pleural group comprises two circular sensoria, the posterior lying ventro-pleurad of the anterior; in the medio-pleural group of plates are two circular sensoria, and in the ventro-pleural group, two circular sensoria and slightly behind these a slender clavate element; circular and clavate sensoria are also present on the last segment.

Stage II

No measurements of the larva can be given as only fragments of the skin, the buccopharyngeal armature and the posterior spiracles have been found.

The skin is transparent and colourless, bearing numerous small short, acute black spines (length, 0.0047 mm.); some rather short, cylindrical, acuminate, pigmented sensoria are also present.

The buccopharyngeal armature (Fig. 4) (length, 0.17 mm.) is characterized by the lack of articulations between its various regions, by the rather broad, slightly arcuate anterior region, terminating in a short acute dorsal, tooth and a broad ventral tooth; the sclerite of the salivary gland is well differentiated, but fused to the intermediate plate on each side; the intermediate region is about half as long and 1½ times as broad as the anterior region; the ventral wing of the posterior region is very short and broad; the dorsal wing, which is about 2½ times as long as the ventral wing, is clavate in outline, joining the dorsal edge of the intermediate at an angle of about 45°; about the middle of the anterior region a little dorsad of the middle, a minute circular foramen can usually be seen. The proportions of the various parts of the armature vary a good deal in individual specimens, but its form is rather distinctive and enables the larva to be distinguished easily from other stages of *leucoptera* and from all known stages of the other parasites of *cerasivorana*. The antenna is short, (length 0.0047 mm.) semi-oval in outline; anterior spiracles have not been found; the posterior spiracles associated with the buccophryngeal armature and belonging apparently to the second stage larva of this species are of unusual form, (Fig. 14) with large felt-chambers only slightly longer than broad; each of these terminates in 3 short clavate spiracular slits, opening in a roughly oval spiracular plate; so that the spiracles in this stage have the same general form as in stage III, though they are very much smaller.

Stage III.

No stage III larvae have been obtained but the characters of the spiracles, buccopharyngeal armature and cuticle can be obtained from the puparium, which also contains the prothoracic respiratory apparatus of the pupa.

The cuticle is delicately striated and transparent, bearing rather widely spaced rows of short, stout (length, about 0.009 mm.) curved dark spines (Fig. 15), the individual spines being usually rather widely separated, the distance between their bases almost twice the length of a spine; the spine bands usually lie adjacent to the intersegmental lines, the spines behind the line directed backward, the spines in front of it directed forward (1); small circular sensoria and short, cylindrical acuminate sensoria (length, 0.027 mm.) are present on most of the segments; the thoracic segments also bear on each side the long slender spine noted in the stage I larva. The anterior spiracles (Fig. 7) are slightly prominent width at broadest part, 0.134 mm., at narrowest part, 0.076 mm.) and consist each of two knobs, bearing about 8 rather large circular respiratory openings. The posterior spiracles are approximately circular (Fig. 6) (transverse axis, 0.160 mm., slightly shorter than the longitudinal axis); the distance between the spiracles is about ½ the transverse axis of one spiracle; the spiracles are about three times the diameter of one spiracle from the anal opening; each has 3 short straight equidistant slits (length, about 0.046 mm.) radiating outward from the spiracular button (moulting scar), (2) the two dorsal slits equidistant from the transverse axis of the spiracles. In the puparium, the spiracles are practically apical; definitely raised, intense black and shining, contrasting strongly with the semitransparent red colour of the remainder of the puparial cuticle.

The pupal spiracles consist only of the internal plate, which is approximately circular (diameter 0.144 mm.) with about 7 vaguely differentiated radiating spiracular slits, bearing from 70 to 80 papillae, the whole structure feebly pigmented; the prothoracic cornicle is absent in this species.

The buccopharyngeal armature of Stage III (Fig. 5) (length, 0.34 mm.) resembles that of stage II in the absence of articulations between the various regions; the acute anterior region terminates in two stout teeth, the ventral tooth curved and about twice as long as the dorsal tooth; this region, from the tip of the ventral tooth to the anterior edge of the sclerite of the salivary gland, is about twice as long as the intermediate region, measured from the anterior edge of the ventral wing of the posterior region; ventral wing of the posterior region somewhat shorter than the anterior and intermediate regions together; dorsal wing of the posterior region very much longer than the ventral wing, not parallel with it but diverging rather strongly dorso-caudad, clavate, rounded at the end; sclerite of the salivary gland well marked, attached to the intermediate region on each side; a small foramen with a sensorial organ in its ventro-anterior angle.

Reproductive Systems

This has not been observed in fertilized females, but unfertilized females, in which eggs had already descended into the uterus, were available (Fig. 3). The ovaries are rather unusual, somewhat oblong in form, with a moderate number of ovarioles (about 10 visible side by side in an optical section), each ovariole comprising 4-6 eggs of approximately the same length and diameter, with no distinct terminal chamber nor any nutritive cells; the paired oviducts are slightly shorter than the unpaired oviduct, which opens into the terminal bulbous part of the uterus; there are 3 spermathecae; the spermathecal capsules are light brown in colour, piriform, the spermathecal duct divided into a slender

[1]The arrangement may be regarded as one permitting the larva to move either forward or backward; a simple morphogenetic explanation of it was suggested by the writer in 1929.

[2]The so-called "button" is really the remains of the orifice through which the "felt-chambers" and tracheae of the preceding stages have been withdrawn at the moult; a better name would therefore be "moulting scar".

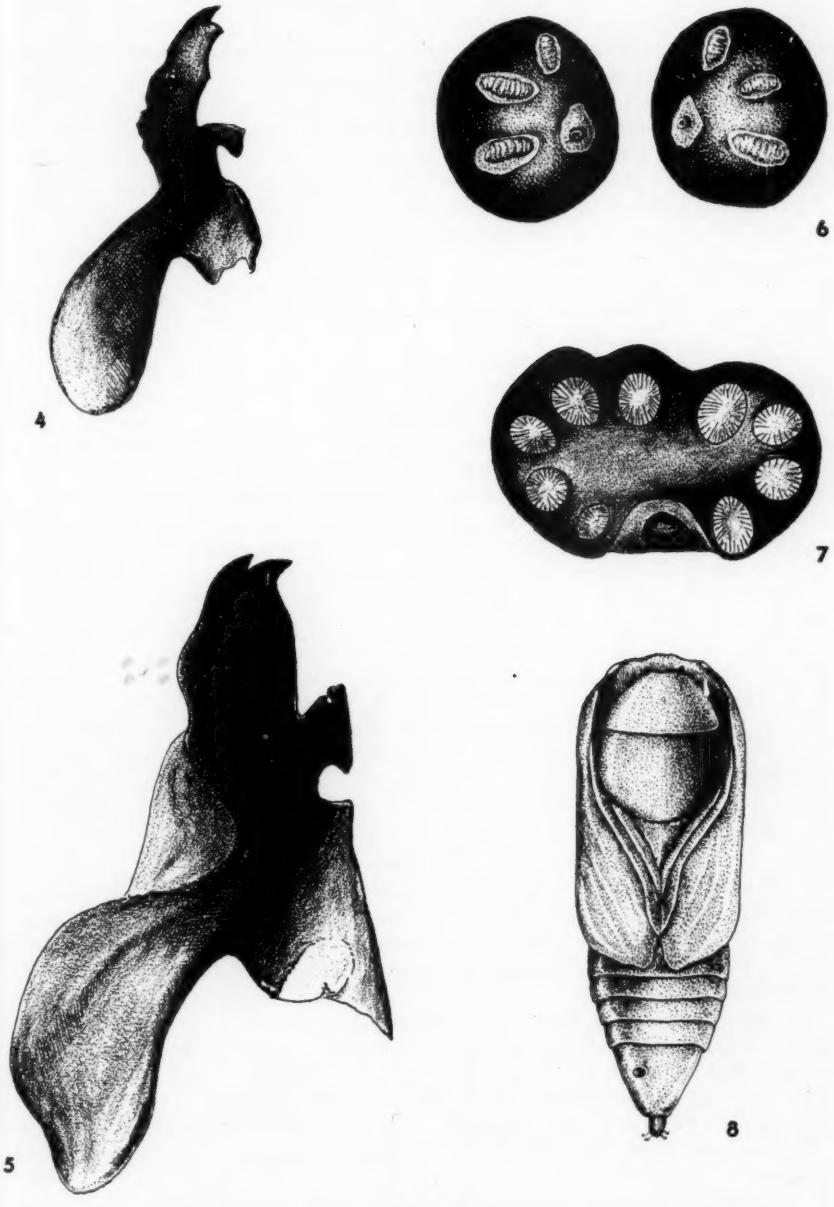


PLATE 2

Dicaetoneura leucoptera Johns.: Fig. 4, buccopharyngeal armature, stage II; 5, buccopharyngeal armature, stage III; 6, posterior spiracles, stage III; 7, anterior spiracle, stage III, showing the ring of respiratory openings and the moulting-scar; 8, pupa of *A. cerasivorana* with unissued puparium of *Dichaetoneura*, showing the opening of the integumental funnel on the last abdominal segment.

distal portion and a lower, enlarged and highly muscularized portion, each about the same length as the spermathecal capsule; the accessory glands are 2 in number, a little longer than the spermathecae with their capsules, cylindrical in form with short ducts; the uterus, in the specimens examined, is moderately elongate and slender (length 0.171 mm.), richly supplied with tracheae. The structure of the reproductive system suggests that *leucoptera* deposits larvae; but the few field-collected adults dissected, have contained only undeveloped eggs. It is therefore possible that this species, like the Rhinophorine parasites of woodlice, lays unhatched eggs which nevertheless produce armoured and migratory larvae; however the terminal segments of the abdomen are adapted for oviposition but not for piercing.

The reproductive system of the male has rather elongate testes, red in colour and well developed, and pyriform collaterial glands. (vide Thompson, 1913.)

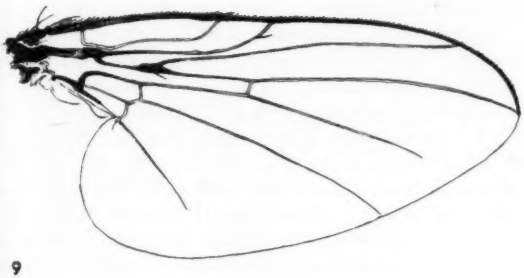
The character of the ovarioles in this species seems worth noting. As is well known, there are three principal types of ovarioles in the Insecta: the *panoistic type*, in which nutritive cells are wanting; the *polytrophic type*, in which nutritive cells are present and alternate with the oocytes; and the *acrotrophic type*, in which nutritive cells are present at the apex of the ovariole, being sometimes connected with the oocytes by protoplasmic strands. In ovarioles of the polytrophic type the nutritive cells are sometimes grouped in chambers separated by constrictions from the oocytes. In others each group of nutritive cells lies above the oocyte in a common chamber. This is the condition normally found in the Lepidoptera and the Diptera, including the Tachinids. As we have noted, no definite germinal chamber, nor any nutritive cells can be seen in the ovarioles we have been able to examine. It is possible that they are of the panoistic type, which Townsend erroneously describes (Manual of Myiology, I, p. 119) as normal in the Tachinids; but it is more likely that their absence is due to the unusually rapid development of the ovarioles, so that very soon after emergence the nutritive cells have been absorbed and the germinal chamber atrophied. A similar condition, though less marked, was described by J. Pantel (1910, p. 75) in *Bigonichaeta setipennis* Fall. and other species classed by him in his reproductive group V.

Biology

The oviposition of this species and its entry into the host have not yet been observed. The larva is of the "planidium" type, and such larvae are usually ready to hatch when they are deposited. However, as has been stated, the field collected females of *leucoptera* that have been dissected contained only undeveloped eggs.

According to A. B. Baird, (18) the larvae of *leucoptera* are situated in the body cavity of the *cerasivorana* caterpillar, just behind the head, where they are attached by means of integumental funnels. When full fed, they "eat their way out through the side of the victim and either pupate in the nest or fall to the ground and pupate under rubbish". The host larvae, Baird states, "may live for some time after the parasites have escaped", though none live to reach maturity.

During the present study, only a few larvae were found in caterpillars. These, which were in the first stage, occupied integumental funnels opening on the last segment, not behind the head. All the host pupae parasitized by *leucoptera* showed, on the ventral side of the last segment, the opening of an integumental funnel, and in this was the skin of the first stage larva, which shows that the respiratory opening was made in this stage. (Fig. 8).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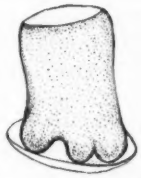
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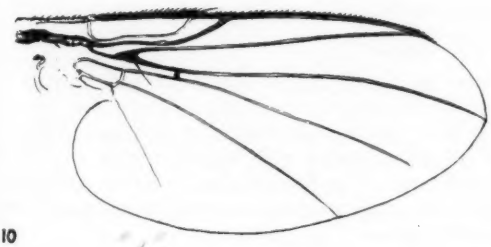
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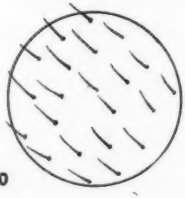
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PLATE 3

Fig. 9, wing of *Dichaetoneura leucoptera*; 10, wing of *Phytomyptera nigrina* Meig.; 11, *D. leucoptera*, posterior felt-chamber, stage I; 12 the same, in end view; 13, *D. leucoptera* antenna, stage I; 14, *D. leucoptera*, posterior felt-chamber, lateral view, stage II; 15, *D. leucoptera* internal pupal spiracle; 18, *Zenillia blanda* O. S., area of wing; 19, *Phytomyptera nigrina* Meig., ditto; 20, *Dichaetoneura leucoptera*, ditto.

It is possible, as has not infrequently happened in work on Tachinid biology, that the larvae examined by Baird were not those of *leucoptera* but of another parasite, possibly the so-called *Exorista boarmiae*, (which, as noted above, was probably *Zenillia blanda*) but the reference to integumental funnels makes this unlikely. Another possibility is that *D. leucoptera* has two generations on *cerasivoraing*, and during the first generation, behaves as described by Baird.

The seasonal history of *leucoptera* presents a puzzling problem. Since it emerges as an adult in the middle of the summer, it must either pass the best part of a year, including the winter, as an adult, or go through in other hosts. The only hosts, other than *cerasivorana*, from which it has been recorded, are the Oecophorid, *Depressaria heracliana* L., which is in the larval stage at the same time as *cerasivorana* (vide Forbes, 1923, p. 243) and the Olethreutid, *Epiblema strenuana* Walk., whose larva bores in Ambrosia (*A. trifida* L. and *A. artemesiifolia* L.). Baird, after noting that adults of *leucoptera* had been kept alive for a month in a cage, suggested that they might hibernate in this condition. Against this is the fact that in flies kept by the present writer, eggs descended into the uterus, even without fertilisation. It seems probable that the parasite hibernates in the larva of some alternate host, rather than as an adult.

Adult

Since *Dichaetoneura leucoptera* is a well-known Tachinid, represented in most collections, a detailed description seems unnecessary. The milky wings, with no posterior cross-vein, (Fig. 9) a fourth vein evanescent beyond the bend, and a vein bearing a large bristle near its costal end; together with the short antenna with a broad, flat third segment, (Fig. 16) bearing an arista thickened almost to the tip with a second joint about four times as long as wide, enable the species to be recognized without difficulty.

However, the characteristic milky wings are of some interest. Townsend, in his key to the "Actiines" (Manual of Myiology, IV, 133) separates a group of genera from the others in the tribe, on this character; but some specialists doubt its generic value.

In *Dichaetoneura leucoptera, Eurycerомyia robertsoni* Tns., and *Melizoneura albipennis* R.-D., the wings are milky and the venation is reduced. On the other hand a number of species with an evanescent fourth vein have clear wings, while in others with milky wings the venation is complete.

It is rather difficult to decide what is the fundamental difference between celar and milky wings. In the species I have been able to examine: *Dichaetoneura leucoptera* J., (Fig. 20) *Melizoneura albipennis* R.-D., *Mesomelaena mesomelaena* Lw., and *Phytomyptera nigrina* Meig. (Fig. 19) the wing membrane itself does not seem to differ from that of the clear wings. On the other hand the small hairs clothing the wing are very different. In the clear winged species they are long, stout, strongly pigmented and rather widely spaced; in the milky winged species they are short, very slender, practically colourless and rather closely set. The figures, showing the number and arrangement of the hairs in an area of the same size in different species, will make the difference clear. When the milky wings are mounted in balsam they become transparent and colourless. It seems, therefore, that the milkiness is due to the reflection of light from the covering of small colourless hairs. The milky colour of the wings is thus due partly to a structural character and is not merely a colour difference.

A point noted during the very cursory study of the wings is that the size of the hairs clothing the wing membrane is not strictly correlated with the size of the wing. In the minute Tachinid, *Campogaster exigua* Meig., the hairs are somewhat less than half as long as those of *Gonia* sp., the wing of *Campogaster*

being slightly less than one-third as long as the wing of *Gonia*. The wing of *Miltogramma oestraceum* Fall., is about twice as long as that of *Campogaster* but the hairs are about the same length. The wing of *Zenillia blanda* O.S. is not quite as long as that of *Miltogramma* but the wing hairs are distinctly longer (Fig. 18). Finally the wing hairs of *Melizoneura* and *Dichaetoneura* are little more than half as long as those of *Campogaster*, though the wings of the two former species are much longer than the wing of the latter.

Systematic Relationship

In erecting the genus *Dichaetoneura* with the genotype *leucoptera*, Johnson ('07) stated that it was closely related to *Phytomyptera* Rondani, but that Rondani's figure of the wing of *Phytomyptera* shows costal setae only to the tip of the auxiliary vein, whereas in *Dichaetoneura* they advance to the tip of the first vein; and are nearly as marked to the end of the second vein; and furthermore that *Dichaetoneura* has a large bristle toward the outer end of the first vein, this being absent in *Phytomyptera*. In fact, not merely the costal setae, but the costa itself is prolonged to the tip of the third vein in *Dichaetoneura* (Fig. 9) but only to the tip of the second vein in *Phytomyptera* (Fig. 10). It may be noted also that the wings are only faintly milky in *Phytomyptera* but markedly so in *Dichaetoneura*, which is a much larger fly.

Curran in his "North American Diptera" makes *Dichaetoneura* a synonym of *Phytomyptera*. The idea that the genera are closely related appears to be rather general among dipterologists. Although Townsend (Manual of Myiology, IV) separates them, he places both genera in his tribe Actiini, which contains such forms as *Actia*, *Craspedothrix*, *Schizotachina* and *Schizactia*. These forms certainly resemble *Phytomytera*. Some species of *Actia* (vide Greene, 1934) even have the evanescent fourth vein. The similarity between the adults of *Phytomyptera* and *Schizotachina* is indicated by the fact that the paratype female of *Phytomyptera walleyi* Brooks, described by this author, was subsequently transferred in the Canadian National Collection to the series of *Schizactia vitinervis* Thomps. The early stages of *Phytomyptera* have not been described. However, the primary larvae and the puparia of the Actiines mentioned above, in so far as they are known, are both characteristic and similar and very different from those of *Dichaetoneura leucoptera*. The primary larva bears only rows of spines on the segmental margins. The mouth-hook is broad anteriorly, not in the form of a curved tooth as in *leucoptera*. The posterior end of the puparium forms a more or less distinct tubercle which in *Schizotachina* and *Schizactia* constitutes a distinct, slender, curved tail. *Schizactia vitinervis*, like *Dichaetoneura leucoptera*, lacks the prothoracic cornicles in the pupal stage; but they are present in *Actia* (or *Gymnophthalma*) *diffidens* Fall., according to Prebble ('35) and as will be shown later, in closely related species, these structures may be present or absent.

The classification of the Tachinids is notoriously difficult. Most authors have contented themselves with providing more or less workable tables to the genera. The great Manual of Myiology of Townsend, useful and indeed indispensable though it is, provides nothing that can properly be called a classification. By far the most impressive and most promising attempt is that made by L. Mesnil, particularly in his "Essai sur les Tachinaires" (1939) and his contribution to Lindner's "Fliegen der Palaearktischen Region" (1944-). In the latter work, Mesnil, having separated the Tachinids from the Dexiids, the Ameniids and the Phasiids, (the Rhinophorids being grouped with the Sarcophagids, the Hypodermids and the Calliphorids in a separate family: the Calliphoridae), proceeds to divide them into three sections: the Goniines (Salmacines) the

Phorocerines and the Echinomyiines (Larvaevorines). The first two of these groups are separated from the third on the character of the prosternum, the orbital bristles, the thoracic chaetotaxy and the spurs at the end of the third tibiae. In the Echinomyiines the prosternum is bare, there are no reclinate inner orbital bristles, the thoracic chaetotaxy is rather poorly developed and there is a well developed inner spur at the end of the hind tibia; in the others the prosternum has lateral bristles, there are reclinate inner orbital bristles, at least in the female, the thoracic chaetotaxy is well developed and the hind tibia lacks the inner spur. All these characters do not always hold good but the exceptions are rare.

In *Dichaetoneura leucoptera* the prosternum is bare. The thoracic chaetotaxy is well developed. However, there are no definitely reclinate inner orbital bristles and there is a fairly well developed inner spur at the end of the hind tibia. In the keys of Mesnil's 1939 paper, the species runs out without much difficulty to the Macquartiini and then to the sub-group Brachymerina though the third longitudinal vein is bristled only at the base and not to the small cross-vein. Until the various forms in this group have been investigated, the position of *Dichaetoneura* must remain in doubt but there seems little reason to class it with the Actiines, still less in the genus *Phytomyptera*.

Acknowledgements

The writer wishes to express his appreciation of the help received in connection with the preparation of this paper from Dr. M. L. Prebble, who authorized the collection of samples of *Archips cerasivorana* by officers of the Forest Insect survey; from Messrs. A. Dustan and D. Groves, who reared the material; from Dr. R. Glen and the officers of the Systematic Unit of the Division of Entomology for permission to examine material in the National Collection and to use certain preparations of larvae made by Mr. A. R. Brooks; and from Mrs. W. R. Thompson, who prepared the illustrations to the paper, using camera lucida sketches made by the writer.

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Notes on the Biology of the Tuber Flea Beetle, *Epitrix tuberis* Gentner (Coleoptera: Chrysomelidae), in the Interior of British Columbia[1]

By C. L. Neilson[2] and D. G. Finlayson[3]

The tuber flea beetle, *Epitrix tuberis* Gent., has been a pest of potatoes in the Fraser Valley and the lower mainland of British Columbia since 1940 (Glendenning, 1942). However, it was first reported from the interior in 1944, at Keremeos and Princeton and in the southern Okanagan Valley (Buckell, 1944). In 1945 and 1946, the first surveys were made to determine the area involved. The area and the degree of infestation have since increased until it is now a very serious pest in the interior. The area of infestation is bounded by the International Border on the south and the Okanagan Valley on the east and extends northward to Malakwa. From here the line runs west through Adam's Lake to Barriere, to Criss Creek, to Pavillion, thence south to Lillooet, Lytton, Merritt, Princeton, and Hedley.

In this paper several aspects of the biology of *E. tuberis* are reported that are closely related to phases of economic control.

The adult has been described in detail by Gentner (1944). It is dull black, and slightly shorter and more hairy than *E. subcrinata*, the only other flea beetle of economic importance found on potato in the interior of British Columbia. The elliptical eggs average 0.5 mm. in length and 0.2 mm. in width; surface reticulate. The newly hatched larva is white to cream-coloured, thread-like, and approximately 1.0 mm. long. The full-grown larva is white, averaging 5.3 mm. in length and 0.8 mm. in width. The pupa is uniformly white and approximately 2.5 mm. long and 1.5 mm. wide across the mesothorax.

Spring Emergence of Overwintering Adults

A survey on spring emergence of overwintering adults, consisting of sweeping the vegetation, mostly weeds, within a half-mile radius of experimental potato plots, was made in the Nicola Valley and Kamloops districts in 1948 and in the Kamloops district in 1949. The survey commenced before any adults emerged and continued periodically until the first adults were captured. In 1948 the first beetles were taken at Merritt on May 28 and at Rayleigh on June 1. In 1949 the first were taken at Westside on May 30 and at Mission Flats on June 3. Observations made during 1950 and 1951 indicate that in areas farther south (such as Osoyoos and Oliver) emergence is even earlier but the exact dates have not been established.

Sex Ratio and Mating

In 1948, all beetles collected from May 30 to June 13 were dissected to determine the sex by examination of the genitalia; the sex ratio of these beetles was approximately 1:1.

Mating took place within 24 hours after emergence; the period of copulation varied, but copulation was repeated intermittently over a period of 60 days. Hill (1946) also observed repeated copulation, and believes that the frequency of mating is influenced in some way by the quality of food.

Preoviposition and Oviposition

A knowledge of the preoviposition period of the overwintering generation coupled with emergence dates facilitates control measures, thus reducing the initial damage and the future population from the two summer generations. The preoviposition periods of both the overwintering and the first summer generation varied from 5 to 8 days, with an average of 6 days for each.

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Finlayson (1950) found that the length of the oviposition period varied, ranging from 12 to 54 days with an average of 37.5 days.

The eggs are laid singly, no uniform number being deposited daily. The maximum number of eggs laid by females varied considerably, ranging from 28 to 203 with a mean of 86.9.

Maturation and Adult Longevity

The period of development from egg to adult emergence was determined by placing mating adults in cages 2½ feet each way. These cages were covered with lumite and placed over potato plants free from adults. Beetles were put into one cage on July 21, 1949, and into another on August 4, 1949; egg-laying for this generation commenced July 24, 1949. On August 15, the cages were removed, the potato plants were cut off about one inch above the ground, and emergence cages with glass exit tubes were placed above the cut stubs of the potato plants. Adults emerged from the first cage on September 1, and from the second cage September 11. The maximum number of days from egg to adult was 39 days in cage 1 and 38 days in cage 2.

The earliest date of emergence for first-generation adults in the Merritt district in 1948 was July 20. No second generation was recorded there, perhaps because of the floods and the unusually heavy rains that year. In the Kamloops area in 1949 the first-generation adults began emerging on July 19; the second generation, September 1.

Adults captured in copulation were caged and the duration of adult life from this period until death ranged from 6 to 106 days with a mean of 56.6 days. The sex of the beetles was determined by dissection. The longevity of the males ranged from 24 to 106 days with a mean of 70.9; the females from 6 to 60 days with a mean of 42.5.

Food Plants

During the investigation the leaves of the following plants were found to be eaten by the adults:—

alfalfa, *Medicago sativa*
dandelion, *Taraxacum officinale*
wild mustard, *Brassica kaber* var. *pinnatifida*
green tansy mustard, *Descurainia pinnata*
tomato, *Lycopersicon esculentum*
radish, *Raphanus sativus*
pepper, *Capsicum frutescens*
bean, *Phaseolus vulgaris*
horse-radish, *Armoracia lapathifolia*
lamb's-quarters, *Chenopodium album*
beet, *Beta vulgaris*
spinach, *Spinacia oleracea*
hollyhock, *Althea rosea*
red currant, *Ribes sativum*
lettuce, *Lactuca sativa*

Whether voluntary feeding on these plants continued after the potato plants were available was not investigated.

Natural Control

There are no published records of parasites of *E. tuberis*. Extensive rearing of larvae and pupae in 1948 and 1949 failed to yield any parasites.

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The Influence of Spray Programs on the Fauna of Apple Orchards in Nova Scotia. V. The Predacious Thrips *Haplothrips faurei* Hood[1]

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Introduction

Lord (1949) listed the predators of the European red mite, *Metatetranychus ulmi* (Koch.), in Nova Scotia and described the effects of a number of chemicals on them. Among the more important predators is the thrips *Haplothrips faurei* Hood. This thrips, however, does not confine its feeding to European red mite eggs but readily attacks the eggs of many other mites and insects. There is strong evidence that it is one of the most important biotic factors in the natural control of insect and mite pests in Nova Scotia apple orchards. It and another species, *Leptothrips mali* (Fitch), are the only thrips of economic significance, and *H. faurei*, because of its greater numbers, is the more important. A description of the life-history of *L. mali* was given by Bailey (1940), who also (1939) studied the biology of another thrips, *Scolothrips sexmaculatus* (Perg.), which is of minor importance in Nova Scotia. The only other predacious thrips found is a species believed to be *Zygothrips minutus* Uzel, which occurs only rarely and in small numbers. *Haplothrips subtilissimus* Hal. (later identified as *H. faurei*), was found by Putman (1942) in Ontario to be predacious on phytophagous mites and the eggs of oriental fruit moth, *Grapholitha molesta* Busck.

The importance of *H. faurei* in the natural control of several major pests of apple has made it necessary to formulate spray programs not destructive to this species. This paper gives the results of studies made to facilitate the development of such a program.

Value of *H. faurei* as a Predator

Studies on this thrips have been supplemented by the investigation of certain pest species and of the manner in which these are influenced by *H. faurei*. It is not possible to express precisely the effectiveness of this predator owing to, (1) the numbers of other predacious species often present in a given environment, (2) unknown factors governing the density of the thrips population, and (3) the fact that *H. faurei* has more than one prey. There is no doubt, however, that this thrips can be effective in reducing a population of the European red mite and, under favorable conditions, in controlling an outbreak. *H. faurei* is a factor in the control of the eye-spotted bud moth, *Spilonota ocellana* (D. & S.), and the codling moth, *Carpocapsa pomonella* (L.), since it also feeds on their eggs. It is doubtful, however, that the eggs of these two pests are ever present in sufficient numbers to cause an increase in the thrips population. The thrips has a comparatively short life-cycle, having about one generation for every two generations of the European red mite. The population often increases considerably (Table I) in one generation where mite prey is plentiful. On many occasions a sharp increase in the numbers of mites was followed, about a month later, by an increase in the numbers of thrips, sufficient to check the mite population. The occurrence of such an increase in the thrips population can have a vital effect on the codling moth and bud moth populations. For instance, a large number of mites in the spring may attract the thrips, which then feed on codling moth and bud moth eggs as well as on the red mite eggs. Under these conditions it has been observed that effective control of these two lepidopterous pests may occur through egg predation.

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Effectiveness on Phytophagous Mites

Although it has always been very difficult to find orchards in which a single species of predator was the only factor of biotic control of phytophagous mites, an unusual situation of this type occurred in 1946 in a small commercial orchard treated with bordeaux and ferbam fungicides and nicotine sulphate as the insecticide. In this block *H. faurei* was the only predacious species found. Owing to a previous program of sulphur sprays there had been a considerable build-up of the European red mite in 1946 with a heavy deposition of winter eggs in the fall. During the following summer large numbers of *H. faurei* reduced the mite population to a very low level, which relationship of predator and prey continued for the succeeding two years.

In an experimental orchard, divided into two blocks, one was treated with sulphur and the other with copper fungicide. In the former the mite was abundant in the summer of 1946 (Table I), and 90 per cent of the heavy deposition of winter eggs were destroyed by *H. faurei*. The latter had a moderate population of the clover mite, *Bryobia praetiosa* Koch, and a light population of the European red mite in 1946; predation by *H. faurei* prevented a build-up of both mite species during the summer and destroyed many of the overwintering eggs.

A third orchard, typical of many orchards in the Annapolis Valley, had been treated for three years with bordeaux and ferbam sprays; it supported a moderate population of the clover mite and a light population of the European red mite early in the summer of 1946. Large numbers of *H. faurei* and a moderate number of typhlodromid mites, also predacious on the European red mite and the clover mite, suppressed the phytophagous mite population in this orchard by September. The relative effectiveness of *H. faurei* and *Typhlodromus* spp. as predators could not be determined, but since both feed readily on mite eggs the thrips, because of its larger numbers, was presumably the major factor.

A medium to heavy population of the thrips is often found in commercial orchards in the summer or fall where the European red mite has been plentiful early in the season and where no sprays detrimental to the thrips have been applied during the spring or summer. For example, in two commercial orchards where observations were made during 1946, it was not uncommon to collect in the early fall, by the jarring method (See "Methods of Study"), from 150 to 200 thrips from each sampling. These numbers represented approximately two thousand thrips per tree. Experience has shown that a thrips population of this size can prevent a mite outbreak, and subsequent examination of these orchards showed good control of the mite by late summer.

Lord (1949) gave more details on these studies.

TABLE I

EFFECTS OF FUNGICIDES. NUMBERS OF *H. faurei* PER TREE SAMPLED BY A DUSTING METHOD[1], KINGS CO., N.S., 1946

Orchard	Fungicide	May 28–June 6	June 25–July 4	July 5–31	Aug. 9–22	Aug. 31–Sept. 13	Sept. 14–20
Wolfe	ferbam	–(L)[2]	114(L)	100(LM)	208(M)	83(M)	60(L)
Hiltz-S. Yar.	sulphur	3(M)	0(H)	5(H)	3(H)	51(H)	81(H)
Hiltz–S. Yar.	copper	9(L)	0(L)	11(M)	30(L)	41(L)	242 (MH)

(1) Dislodging the arthropods from the tree by a quick-acting toxic dust.
(2) L : phytophagous mite population light; M, moderate; H, heavy.

Effectiveness on the Eye-spotted Bud Moth

The eye-spotted bud moth, *Spilonota ocellana* (D. & S.), is present in moderate numbers in most orchards in Nova Scotia. This pest is evidently normally held in check by a complex of factors, including both parasites and predators. When predacious thrips, mirids, and anthocorids attack this bud moth they confine their attacks largely to the eggs. Though it is difficult to determine the amount of predation caused by *H. faurei*, it has been observed in some orchards that this thrips was the only predator sufficiently numerous to be effective (Stultz, in preparation). In one such orchard where the thrips population had built up on phytophagous mites, 69 per cent of the bud moth eggs failed to hatch largely because of thrips predation. In a comparable orchard where no predators were observed only 11 per cent of the bud moth eggs failed to hatch.

In small-scale studies, under controlled conditions, on *H. faurei* as a predator of the bud moth eggs, this thrips destroyed a major portion. The density of the thrips population depends largely on the numbers of phytophagous mites present over a one- to two-month period, but its effectiveness against the bud moth may be decreased when mite eggs are easily found by the thrips during the period of abundance of the bud moth eggs.

Effectiveness on the Codling Moth

H. faurei will feed readily on the eggs of the codling moth, *Carpocapsa pomonella* (L.), in laboratory rearing cages. In one cage one adult and two nymphs consumed the contents of 14 out of 17 codling moth eggs in 36 hours. In another cage one adult destroyed 6 out of 9 eggs in 48 hours. The thrips has also been observed feeding on codling moth eggs in the orchard. Studies of *H. faurei* preying on the codling moth, carried out by C. R. MacLellan of this laboratory, indicate that where the thrips is present it is an important factor in the destruction of codling moth eggs. However, owing to the activity of other predators it has not been possible to accurately assess its value.

Effects of Chemicals on *H. faurei*

Of the chemical sprays commonly used in Nova Scotia apple orchards for the control of apple scab and insect pests, some kill nearly all *Haplothrips faurei* but others have little or no effect on its numbers. In recommending orchard spray programs in Nova Scotia the effects of spray materials on the thrips population are now considered.

A number of small-scale experiments were carried out to determine the effects of a number of materials on *H. faurei* and the results of some of the tests are given in Tables I, II, and III. Observations were also made in many experimental and commercial orchards and it is now possible to make reliable estimates of the influence of spray applications on this species.

DDT, parathion, and BHC practically eliminate the thrips populations and sulphur causes a marked reduction. Table I shows that although the phytophagous mites were numerous on the sulphur-treated plot, the thrips population was very low until well after the spraying season, which ended in late July. General observations in commercial orchards where sulphur sprays were used substantiate the experimental evidence.

A second group of spray chemicals, including the fungicides Phygon and Tag (10 per cent phenyl mercury acetate) and the insecticides cryolite, nicotine sulphate, and summer oil caused some reduction in the number of the thrips. Results of tests with these substances (Tables II and III) indicate that the effect

is not drastic. In certain circumstances applications of nicotine sulphate have not reduced the effectiveness of the thrips in controlling phytophagous mites.

A third group of spray chemicals, the fungicides ferbam, copper mixtures (Table I), and Crag Fruit Fungicide (Table III), as well as the arsenical insecticides and fixed nicotine (Table II), apparently cause no reduction in populations of *H. faurei*. Except fixed nicotine, all of these substances were used on large acreages, and in no case was the population of thrips significantly affected or the control of phytophagous mites by the thrips unsatisfactory.

TABLE II

EFFECTS OF SPRAY CHEMICALS ON *H. faurei*: G. WEST ORCHARD, KINGS CO., N.S., 1948

Plot (2 trees each)	Treatment, Aug. 16 Amount per 100 gal.	Numbers of larvae and adults collected on August 19 by jarring	
		Alive	Dead
check	none	68	14
1	DDT, 2 lb. (50% w.p.)	0	0
2	parathion, 0.5 lb. (15% w.p.)	0	52
3	parathion, 2.0 lb. (")	0	47
4	Phygon, 1 lb.	0	15
5	nicotine sulphate, 1 pt.	6	25
6	fixed nicotine, 4 lb. (BL 155)	46	15
1D	DDT, 2 lb. (50% w.p.)	2	6
2D	parathion, 0.5 lb. (15% w.p.)	0	55
3D	parathion, 2.0 lb. (")	0	62
4D	Phygon, 1 lb.	1	33
5D	nicotine sulphate, 1 pt.	5	11
6D	fixed nicotine, 4 lb. (BL 155)	13	3

TABLE III

EFFECTS OF SPRAY CHEMICALS ON *H. faurei*: ILLSLEY AND HEWITT ORCHARDS, KINGS CO., N.S., 1949

Treatment Amount per 100 gal.	Numbers collected by jarring			
	Illsley orchard, 3-tree plots. Sprayed July 18. Jarred July 20, Aug. 1 and 12		Hewitt orchard, 2-tree plots. Sprayed July 29. Jarred Aug. 10 and 17.	
	Adults	Larvae	Adults	Larvae
summer oil, 1 gal.	31	7	8	6
cryolite, 4 lb.	46	29	37	5
nicotine sulphate, 1 pt.	49	25	—	—
micronized sulphur, 8 lb.	15	9	46	4
flotation sulphur, 15 lb.	18	7	19	1
Phygon, 1 lb.	23	12	95	46
Arathane (25%; Rohm and Haas Co.), 1.5 lb.	140	18	—	—
HL-331 (Tag), 1 pt.	40	10	62	11
Crag Fruit Fungicide (341C), 2 pt.	138	5	225	25
DDT, 2 lb. (50% w.p.)	—	—	11	9
parathion, 0.75 lb. (15% w.p.)	—	—	19	23
check	262	31	175	32

Biology of *H. faurei*

Description

Haplothrips faurei was described as a new species by Hood (1914) from females collected on ivy foliage at Ithaca, New York, and on willow leaves at Florida, New York, where it was reported as predacious on mites. The only further references to this thrips are those by Putman (1942) to *H. subtillissimus*, later identified as *H. faurei*, and by Lord (1949).

Adult

The adult is small, shiny black, and approximately 1.5 mm. long and one-fourth as wide. The antennae are eight-segmented, the proximal two segments being dark brown, the remaining six pale yellow with the terminal two shading gradually darker. The wings are transparent, are fringed with long hairs, and at rest lie folded on the dorsum, reaching to the eighth abdominal segment. The legs are black with the distal ends of the tibiae and the tarsi usually light and the prothoracic tibia entirely light.

Egg

The egg is ovoid and about 0.39 mm. in length and 0.14 mm. in greatest width. It is pale orange-yellow and the micropylar tip has a white, raised cap.

Larva

The full-grown larva is fusiform in outline and is about the same size as the adult. The head, the antennae, the legs, and the two large plates on the dorsum of the prothorax have a smoky translucent appearance. The remainder of the prothorax, the metathorax, and the third and fourth abdominal segments are bright red. The mesothorax and the first, second, fifth, and sixth abdominal segments are deep yellow with a slight orange tinge. Abdominal segments seven and eight are pale red which merges with the yellow of the sixth segment. A ring of clearly visible fine hairs encircles the distal end of the last abdominal segment of both the larva and the adult.

Pupa

The pupa is about 1.6 mm. long and 0.38 mm. wide. The head and the appendages are transparent glassy white except that the red contents show through the head capsule. The remainder of the body is reddish-orange. The antennae of the pupa are appressed backward to the lateral surfaces of the head. The wing pads reach the fifth abdominal segment.

Methods of Study

The study of *H. faurei* presented some difficulties because of its small size, active movements, and predacious habits. Some rearing tests were undertaken in the laboratory but most of the information was obtained from field studies.

Rearing

The laboratory rearing method used during the early summer was similar to that described by Putman (1942) in his studies on *Haplothrips subtilissimus* (Hal.). The thrips were confined individually, or in small numbers, and were fed on eggs of either the European red mite, *Metatetranychus ulmi* Koch, or those of the two-spotted spider mite, *Tetranychus bimaculatus* Harvey. The humidity in the rearing vials was an important factor in successful rearing; both adults and larvae die in a few hours if left in a dry vial with a dry stopper. Vials with moistened absorbent cotton stoppers covered with cloth were satisfactory. In the fall when European red mite eggs are laid on the calyx end of apples, a celluloid cage fitted over the apple calyx makes a satisfactory rearing chamber for this thrips.

Field Study

To determine the life-history of *H. faurei* it was necessary to sample the thrips populations throughout the growing season. Of a number of methods used, the three outlined below proved the most satisfactory.

Visual.—Counts were made of eggs and small larvae on opening leaf clusters, on the leaves, and on the apple calyxes with the aid of a binocular dissecting microscope.

Jarring.—Adults and large larvae were dislodged by jarring the smaller branches of the tree. One operator jarred the branches while another held a cloth tray beneath the limbs. The dislodged arthropods were then counted and the thrips collected for identification. This technique was particularly suitable for sampling populations of the thrips, as it is easily dislodged by jarring and it does not readily fly off the tray.

Dusting.—A quick-acting toxic dust, 6 per cent DDT, 10 per cent derris, and 30 to 40 per cent pyrethrum, applied to apple trees with a small power duster immobilized many of the arthropods so that they fell from the tree. Samples of specimens were collected in paper cones suspended under the tree and the specimens preserved for identification.

Life-History

The stages in the life-history of this thrips seem well integrated with the stages of development of the European red mite. The overwintering brood of adult thrips feed on the mite eggs until the latter hatch. For a short time thereafter they feed on the quiescent mites and the eggs of other mites. The hatching of the thrips eggs coincides closely with the deposition of the first generation of the red mite eggs. For the rest of the season there is usually sufficient overlapping of the mite generations for mite eggs to be present on the leaves at all times. The time required to complete one generation of the thrips is short compared with that of many predators, and the longevity of the adults also contributes to its effectiveness. Studies on the life-history, though not extensive, served as an aid in understanding the role of this species in the faunal complex of the apple tree.

Small numbers of individuals of *H. faurei* reared individually in the insectary averaged 12 days for the development of the eggs, 15 days for the larvae to reach the prepupal stage, and 6 days for development from prepupal to adult stage, the average total time from egg to adult being 33 days.

This insect overwinters only in the adult stage and becomes active by early May, at the time the apple leaf-buds are opening. It is not known where it overwinters; however, occasionally a specimen has been found on apple tree branches during winter examinations. The adult thrips are plentiful in the spring in orchards where they have been numerous the previous fall. Egg-laying begins as early as May 22; the eggs are numerous by June 1, and the first-generation eggs hatch during the latter part of June (Table IV). Egg laying decreases after June 15 but overwintered adults continue to lay a few eggs until July 15. The first-generation adults appear about July 15, rendering it impossible after this date to distinguish between the first-generation and the overwintered adults. By August 1, 1947, 95 per cent of the population was in the adult stage. In many of the orchards where mites were abundant, adults thrips were numerous from August until late fall. The second-generation larvae hatch over a long period and many, probably the major portion, reach the adult stage before fall.

The overwintered adult thrips die in early- or mid-summer. Many of the first-and second-generation adults live through the winter. The third-generation eggs are laid and many hatch but it is doubtful whether any of the third generation reach the adult stage and survive the winter.

TABLE IV

DEVELOPMENT OF *H. faurei* AS DETERMINED FROM SUCCESSIVE FIELD COUNTS. (FIGURES ARE BASED ON SAMPLES OBTAINED BY JARRING OR DUSTING IN ORCHARDS IN KINGS CO., N.S. WHERE THE THRIPS WAS PLENTIFUL)

Period	Total	Adults %	Larvae %	Pupae %	Eggs		
					100 clusters	100 leaves	100 apple calyxes
May 16–30	124	100	0	0	46	–	–
June 1–15	88	99	1	0	81	–	–
June 16–30	101	67	33	0	5	4	–
July 1–15	639	50	47	3	–	5	–
July 16–30	1569	74	26	0	–	31	–
Aug. 1–10	95	96	4	0	1	43	–
Aug. 10–15	1087	48	52	0	–	18	4
Aug. 9–22[1]	323	28	72	–	–	–	1
Aug. 31–Sept. 13[1]	236	36	64	–	–	4	–
Sept. 14–20[1]	424	46	54	–	–	–	10

[1]Sampled by dusting, 1946; others, jarring, 1947.

Food and Habits

The active forms of *Haplothrips faurei* in apple orchards are usually found associated with the European red mite, or with the clover mite. The larvae and adults will feed for long periods solely on the eggs of one or of the other species, rarely attacking the active mites when eggs are plentiful; but, when confined in cages and in the absence of eggs, they will attack the mites in any stage.

This thrips will also live and mature on the two-spotted spider mite, on a granary mite (a tyroglyphid), or on the eggs of the eye-spotted bud moth. It has also been observed to feed on the eggs of predacious mites, *Typhlodromus* spp., on cecidomyid larvae, and on codling moth eggs. It is occasionally cannibalistic when confined in cages, feeding on both eggs and pupae of its own species.

The thrips apparently finds its prey by random searching, since even when starved a thrips may pass close to a mite egg and fail to find it. When a suitable prey has been located the thrips poises above it and places the mouth cone against the prey, puncturing the surface by a slight rotating movement of the head; observations indicate that the mandible does the piercing. The maxillary stylets are then inserted into the prey and are moved in a jabbing, whipping motion, the mouth being in contact with the surface of the prey during feeding.

Both larvae and adult thrips are very active and usually move about with the abdomen held in a distinctive pose, the posterior tip being bent upward and forward. The adult is a comparatively weak flyer but apparently is capable of flying from tree to tree or from tree to ground.

Egg-laying in the early spring is confined to the area of trichomes on the stems of the leaf clusters. After the leaves have opened and have reached nearly full size, the thrips begin egg-laying along the midribs of the leaves. In late summer and fall, when the red mite eggs are on the calyx ends of the apples, the thrips begin egg-laying there and they are often found in the calyx basin.

Discussion of *H. faurei* populations

Although the exact relationships between the populations of this thrips and of its prey have scarcely been touched on in these studies, certain general facts are apparent from limited quantitative observations. The thrips has a moderately high reproductive rate and the adults live for months or possibly even a year or more. Two to three generations occur annually and each thrips is capable of preying on many phytophagous mite eggs per day. These characteristics make this species one of the most important predators in apple orchards in Nova Scotia. There are times, however, when the thrips cannot be found even though conditions seem ideal for it and prey is abundant.

The density eventually reached by thrips populations is largely correlated with the numbers of mites present, with the numbers of competitors for the prey, and with the kind of sprays applied. Under favourable conditions, the thrips will usually overtake a mite population on apple trees in one season or less where the nucleus of a thrips population exists in the spring on the apple trees or surrounding vegetation. The extent to which the thrips move from other plants in or near the orchard to apple trees is not known but they are capable of flying from plant to plant. The evidence of population relationships strongly indicates that the thrips is a density-dependent factor in regulating phytophagous mite populations.

As mentioned above, the thrips feeds readily on eggs of the codling moth and the eye-spotted bud moth. It must, however, first build up on mites and, therefore, is largely a density-independent factor in regulating populations of the codling moth and the bud moth.

In many instances where the populations of phytophagous mites reach moderate or high levels they are reduced by both thrips and typhlodromid mites. After the peak of host abundance has passed, the numbers of thrips tend to decrease gradually, eventually leaving the typhlodromids as the more important controlling agent at the low population densities.

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